

No time to be squabbling

A ROUTINE day at the United Nations in New York? No, a session at the Congress of the World Meteorological Organisation, one of the UN's specialised agencies, held recently in Geneva. At the end of the debate, South Africa was suspended from WMO until it renounces its policy of racial discrimination. The voting was 66 in favour, 25 against and 14 abstentions. In the same session the congress voted 81-14 to invite to WMO meetings observers from National Liberation Movements recognised by the Organisation of African Unity or the League of Arab States. Thus do some international scientific organisations conduct themselves these days; already the Food and Agricultural Organisation, UNESCO and the World Health Organisation have taken comparable restrictive measures against South Africa, and the recent Israel affair still causes a good deal of embarrassment at UNESCO.

The very existence of South Africa is, of course, an affront to a majority of nations—indeed many of those who voted to retain South Africa in membership spoke of their abhorrence of her racial policies. And the depth of feeling can never be fully appreciated by the oppressed whites of Europe. Nonetheless these latter also have deep feelings about the nature of science and the need for its pursuit to be free from politicisation, especially of the amateurish and self-congratulatory type. It is to the credit of the International Council of Scientific Unions (ICSU) that it has thus far been able to stand clear of most of the political nonsenses—although this has been at the expense of China's membership, since she resolutely refuses, despite all invitations, to be alongside Taiwan in the same meetings. It is also to the credit of the UNESCO staff that what gets to the conference table in that assembly has so far generally been universally acceptable.

But the question is bound to be asked—is the international science scene becoming increasingly politicised these days?

Was it ever otherwise, retort some of the wiser folk in the business—it's just that these days the west can be outvoted every time, so the politics are not those favourable to western countries; remember how the west used to vote to exclude China. This is a sane historical point of view, and history teaches us why people's present

attitudes are what they are. Historical perspective, however, also gives us the opportunity to learn from the past in order not to re-live it. And one thing that ought to have been learnt is that the isolation of scientific and other intellectual pursuits, particularly from bodies which claim to be representative, profits no-one and is a futile gesture in the face of strong regimes.

There is another reason why the politicisation of science is particularly inappropriate at present. If voting in United

Mr Tsou-Ching-meng (China) deplored the regime imposed by white racialists in South Africa. His delegation considered that the proposal to suspend South Africa from Membership was right and proper. He stressed the sympathy of the Chinese people towards those struggling against colonialism and racialism in South Africa.

Mr Degefu (Ethiopia) expressed his delegation's condemnation of the South African policy against non-white Africans as well as of that country's occupation of Namibia. Despite repeated condemnations, South Africa had not renounced its policy of racial discrimination.

Mr Pojani (Albania) announced his full support of the proposal to suspend the Membership of South Africa. He deplored the aid given by imperialistic powers which enabled the South African regimes to continue.

Mr Fonseca (Portugal) stressed that the democratic country he represented had nothing in common with the Portugal of 1974, which had been a colonial and fascist one. His Government severely condemned all forms of oppression, discrimination and inhuman treatment. He regretted that none of the documents made any mention of the new Portugal.

Nations bodies were regularly to divide broadly such that developing countries, with their built-in majority, were able to force the pace against the developed countries which supply the money, then it is not inconceivable that an issue could arise on which the developed world decided it had had enough and would keep its money to itself. As yet there is no sign of this, but UNESCO is bound to be particularly closely watched in the coming year with its new Director-General, Mr M'Bow from Senegal, representative of the shift of power towards the developing countries. He will need to pursue a diplomatic path, and will not be helped by divisive confrontation.

But lest it be said that we are defining divisiveness as that which comes from the developing world, it should be added that some of the initiatives of the developed world seem only capable of generating bad feelings. Massachusetts Institute of Technology, which is negotiating a development contract for water resources in Saudi Arabia, is, it is reported, threatening that any act of religious discrimination will cause the contract to be cancelled. Saudi Arabia can hardly welcome Jews with open arms; it surely behoves MIT to use restraint and not to trigger confrontation by insisting on sending them. □



Some progress on the law of the sea

An indication of the slowness of the rate of progress at Geneva in the Third UN Conference on the Law of the Sea is the fact that at least two more sessions are now envisaged; the next will be convened in a year's time at UN Headquarters in New York. Little likelihood is therefore seen of an acceptable convention being hammered out before the end of 1976 at the earliest and it could not possibly come into force for at least two years after that. Progress has definitely been made, however, not least with the proposals covering scientific research.

DELAY has its dangers and there is still a strong possibility of a complete collapse of the negotiations on the law of the sea, which would be disastrous for developed and developing countries alike. Appeals have once again been made for countries to resist the temptation to take unilateral action before agreement is reached, though the patience of some of them is wearing thin and each year is likely to see further arbitrary claims being placed on statute books by geographically advantaged countries, such as the Latin American States, the USA and Iceland, followed by Canada, Mexico and Norway. Fortunately most nations are, so far, showing definite signs of restraint in staking their claims.

One of the chief stumbling blocks to negotiation is the multiplicity of groupings. It is not a case of two groups of states, 'developing' and 'developed', with clear negotiating positions. There are the geographically-advantaged (Argentina, Brazil, Canada, Kenya, the UK, the USA, and so on) and the geographically disadvantaged (led by The Netherlands), the coastal and the land-locked, the shelf locked, the island states, the archipelagic states and so on, all with different needs, wishes and ideas; each grouping overlaps inextricably with the others. There is little doubt that time is on the side of the geographically advantaged states—the concept of the 'Common Heritage of all Mankind' has been severely mauled and is unlikely to survive, except in a very weak and hardly recognisable form; this is mainly because of the activities of geographically advantaged developing states, rather than deve-

loped ones, though Canada has been conspicuously present at the kill.

Negotiating should now start in earnest both in the inter-sessional period and at the next session, though the stated likelihood of a further session after New York "if needed" in summer 1976 will tend to discourage such a move. Three weeks before the end of the conference, however, the chairmen of the three committees were asked to prepare an informal single negotiating text to serve as a procedural device to provide a basis for negotiation. This appeared on the last day of the session and, following scenes of copy snatching from other delegations' pigeon holes, the delegates departed to reconsider and reformulate their positions in preparation for the next occasion. It is vitally important that countries accept this text as a basis for negotiation; if they do not, there is little hope to be seen for any agreement in the foreseeable future.

Countries are still tending to wait for the so-called negotiating phase and, as a result, statements in public often differ quite considerably from the views put forward by the same delegate informally outside a meeting. One of the most surprising positions is that of India, which has in the past benefited almost more than any other developing country from international marine scientific research projects such as the International Indian Ocean Expedition but has been one of the leaders (in public) of the hardliners against any compromise on scientific research in the oceans. There should, in India's view, be no scientific research without very close control by the coastal state or an international authority.

The right to carry out marine scientific research suffered so much from a number of strong statements both for and against that the Chairman of the US Delegation (which came in for praise for the flexibility of its approach to the conference) stated in his closing statement, "I am particularly dismayed by continuing attempts to place restrictions on the conduct of marine scientific research. Knowledge of the oceans is important to all of us. Good science is free science; it is not a commodity that can be packaged and purchased in predetermined quantities. The conference should concentrate on means to ensure that all will enjoy the fruits of science, not on means to restrict science for fear it will only benefit the few".

Shortly before the end of the conference, and it was almost as if this document had not been noticed by the USA (or perhaps the Chairman of the Delegation had finalised his statement by then), a most unlikely group of developing countries, led by Mexico, which country has shown throughout

an excellent grasp and understanding of the problems involved, presented a highly skilled compromise document entitled Draft Articles on Marine Scientific Research. This document has avoided most of the pitfalls which have proved unacceptable to one faction or another and should provide a real basis for the relevant part of the convention. Certain of the articles are, however, likely to be used by the developing countries as negotiating elements for improved arrangements for Transfer of Technology, including training and education in the marine sciences.

One of the strengths of this text is the way in which the controversial matter of fundamental as against resource-related research, has been dealt with. The onus is now placed on the coastal state involved to decide under which category an outsider's research programme falls. No doubt something like 90% of marine research will fall in the resource-related category but rules for conduct of such research, with the full consent and participation of the coastal state, are also provided for.

Unfortunately the author of the informal single negotiating text had failed to appreciate this approach and had gone back to some of the earlier, less informed proposed texts which call for the promotion "through competent international organisations of the establishment of criteria and guidelines concerning the differentiation between research directly related to the exploration and exploitation of the living and non-living resources and fundamental research which is not directly related to exploration and exploitation of such resources"—a virtually impossible task. This text also still contains the fundamental error of linking exploration and exploitation, two completely different activities which should have separate regulations governing them. The former should be encouraged by all, in particular the developing countries, the latter clearly needs close supervision to ensure that any consequent profits are equitably distributed, that renewable resources are not destroyed in the process, that coastal states' rights are fully taken into account and so on.

The other bright spot in the conference has been the work done by an informal group chaired by Minister Jens Evensen of Norway which has developed a series of texts of draft articles on the 200-mile economic zone. This group of senior delegates from about a third of the countries present has had to deal with many diverse matters and interests, such as full use of fish stocks, size of allowable catches, historical rights, access to resources by other countries and so on. These will all be used as negotiating points in what will probably be the key to the

convention, as most developing countries are more interested in immediate benefits which are seen to lie in their economic zones than more distant and less identifiable goals. No agreement on the economic zone will mean no convention. So far, however, the landlocked countries, which consist of two factions — those from Europe (like Switzerland and Austria) and the dozen or so from Africa—and the geographically disadvantaged states, consider that their interests have not yet been sufficiently taken into account.

Far more sinister are the activities proposed in the negotiating text for an International Seabed Authority. For instance, under a paragraph entitled "Contracts for Associated Operations", it says, "the Authority may enter into a contract, joint venture or any other such form of association, for the conduct of scientific research, or for the carrying out of a general survey or exploration of the Area . . ." It seems that under these plans the authority would have the right to deny access to the sea bed or to charge heavily for it. The structure proposed in the draft articles for the authority would be large and costly; in fact, it would virtually amount to the setting up of another new UN body which, in the present economic climate, many countries are determined to avoid. Certain of these countries would be prepared to see an authority formed provided it was self-supporting; that is, if its costs were covered by its income from contracts and exploitation licences. The most optimistic estimates are only for three or four contracts a year in the international zone for the foreseeable future and this would certainly not maintain an authority of the size envisaged. Almost certainly the conference will soon start to look to the existing UN bodies, to see if one of them, such as the Intergovernmental Oceanographic Commission (IOC) or the Intergovernmental Maritime Consultative Organisation (IMCO), could be expanded to take on additional tasks or if a new grouping could be formed.

It is clear from the Geneva manoeuvres and deliberations that the chief interests of the developing countries lie, quite rightly, in the exploitation of living and mineral resources in the economic zone and in Transfer of Technology. Marine scientific research, instead of being called for urgently, is looked on with suspicion by countries who should know better and is being lumped with such matters as Coastal State Control of Ship-generated Pollution, the setting up of the International Sea-bed Authority for the International Zone, and numerous other matters of lesser interest which will be used as bargaining counters for immediate benefits. □

KENNETH MELLANBY



Weather vein

It is a common experience that when a subject which has previously caused us little concern comes to our serious notice, we seem to find ourselves hearing about it repeatedly. In my own recent experience, climatology is such a subject. In February this year I went to the island of La Gomera in the Canaries, to advise on possible agricultural and other developments. My remit was that developments should not adversely affect the ecology of the environment and should, if possible, encourage native flora and fauna.

La Gomera is nearly circular, some 12 miles in diameter, and it rises sharply to a height of nearly 6,000 feet in the middle. The highest land is covered by the remains of the original forest, most areas have been terraced and cultivated (though many farms have been abandoned) and the population is decreasing. For some years the weather has been unusually dry, and this February—at the end of what should have been the wet season, though little rain fell—the land was parched except where there was irrigation and the tanks, intended for use during the dry summer, were empty.

There are undoubtedly substantial water deposits on the island, but we do not know their capacity, nor how long they will be able to continue to supply fresh water before this is seriously contaminated with salt from the surrounding and underlying seawater. With a good rainfall, such as occurred fairly regularly until recently, the deposits were recharged.

A local consultant is optimistic, claiming that the sunspot cycle will ensure adequate rain in the next 18 months. Other experts are not so sanguine, however. To make a rational plan, climatological information is desperately needed. On it depends the future for the local farmers as much as that for those concerned with a very interesting and unusual development. La Gomera is only a tiny island, but it does epitomise a problem affecting vast areas in many continents, not least those of the Sahel

area in adjacent Africa.

I had this example in mind when I attended a recent forum on "Neglected Research", where I heard how the pioneer work of Professor H. H. Lamb's Climatology Unit in the University of East Anglia had been completely denied support from any of the research councils. Yet when I was working on the water problems of La Gomera, I found that expert opinion, not only in Britain but also in other countries, always came back to the recognition of our current ignorance, and to the long-term importance of the work being tackled at Norwich by Lamb and his colleagues. It is difficult to understand why support is denied to a unit concerned with such an important and practical problem area, in which there is a good chance of some success.

It is generally believed that we in Britain have evolved the fairest and least corrupt method for sharing out research funds, even if it is so time-wasting. Many of our most eminent scientists sit day after day on the committees which make the recommendations on how grants should be given or withheld. This thankless task is carried out with care and, if possible, without undue bias. It would be cynical to suggest that those who give up so much of their time do so, partly, because this increases their chances of securing a substantial sum for their own work or for that of their department. It is true that we read in the minutes—"Professor Blank retired during the discussion of this item"—and then, surprise, surprise, follows the announcement that Blank's application for £50,000 has been successful. After all, Blank was put on the committee because of his expertise, and he would obviously not put forward a silly proposal! And occasionally a member's application is turned down. Yet the Lamb incident shows that our situation is not perfect. Even more serious, many unsuccessful and trivial research proposals do receive substantial support, and there is little to show for it.

In a field like research where chance plays so large a part, the very care with which we approach the problem may be a cause of its imperfections. I know, from my own experience, that one of the most substantial grants which led to marked research productivity was given on the whim of a minister and not on the advice of an expert committee. The trouble today is that such large sums of money are involved that we tend to build in complications which may waste much of that money. We forget that original research was once comparatively inexpensive. A plea for more small grants for unfashionable studies might produce unexpected results. □

international news

THE Moscow Sunday seminars are more than a stop-gap for *refusnik* scientists awaiting a visa for Israel. According to their founder, Professor Aleksandr Voronel, who has recently been lecturing in the USA and Great Britain on the international implications of the seminars, they mark an important new development in Soviet science—the establishment of an “alternative” scientific community, which may well have considerable importance for world science as a whole.

When the original fifteen mathematicians and physicists met for the first such seminar in 1972, one of them, Professor Veniamin Levich, joked that it reminded him of his youth, to be back in a group who spoke of nothing but science. This, says Professor Voronel, pinpoints the position of “official” science in the Soviet Union, where, according to orthodox political thinking, “science cannot be non-Party, but must serve some political end”. Although few scientists probably hold this view seriously, anyone who wants to go on quietly living and researching in the Soviet Union must at least subscribe to it formally, and, accordingly, meetings of official scientific bodies, from the Academy of Sciences downwards, cannot be conducted in a spirit of pure scientific enquiry, but will inevitably have some political overtones.

Accordingly, when, one by one, the *refusniks* were dismissed from their jobs, in spite of all their difficulties, they found themselves, for the first time in their professional careers, in the ideal state of “scientific detachment”. Accordingly, the seminars began to attract not only would-be emigrants and Jews, but other scientists such as Yuri Orlov, Andrei Tverdokhlebov, Valentin Turchin, and Academician Andrei Sakharov. Some members of the group, although wishing to emigrate, have not, as yet, been dismissed from their posts. In spite of a certain turnover in the membership as some participants at last received their visas, the membership has steadily grown and, as at now includes more than 50 people, including 8 professors and 20 Candidates of Science (PhDs). In addition to the main Moscow group, there are members in several other cities who travel to Moscow when papers of particular interest to them are scheduled.

In spite of official attempts to crush the seminar (including, in Professor

Soviet seminars are growing

from Vera Rich



Voronel: new development

Voronel's opinion, the *volte face* of the emigration authorities in granting him an exit visa, and recent harassment of the leading members) it now exists as “a scientific community with a good tradition, independent of official organisations and of official policies”. This, Voronel says, is a new and important development in Soviet Science, and he urges that western scientists should do all in their power to assist it.

Except in particular cases, such as psychiatry, in which scientific practice is distorted to accord with political theories and aims, he is opposed to any policy of a western boycott of Soviet science. A boycott, he says, may be “more high-principled”, but is far less productive. It is not the scientists themselves who are responsible for Soviet science policy, but the officials, and the more contacts which can be established between western scientists and their Soviet colleagues, the better.

It is necessary to distinguish, however, between what Professor Voronel calls “free” and “monopolised” contacts. A regular feature of almost every international congress or conference to which Soviet scientists are invited is the arrival, not of the expected delegate, but of some substitute appointed not on the grounds of academic merit but for reasons of political expediency. In such cases, Voronel's message is clear: accept no substitutes. If the expected delegate fails to arrive, then

a boycott of his replacement's lecture will effectively stress the desire of western scientists for free exchange and their refusal to be dragged by Soviet planners.

In so far as “free” contacts can be established, however, Professor Voronel is all in their favour. Although his attempt to hold an International Seminar in Moscow in 1974 was effectively broken up by the authorities, who arrested and hounded the leading members of the group and refused visas to the foreigners wishing to participate, contact between the seminar group and western scientists can still, he maintains, be accomplished. He suggests that any scientist visiting Moscow for an “official” conference, should, on a Sunday, make every possible effort to detach himself from the formal programme, and make his way to the seminar. Such a visit, he says, would not only be of interest to the scientists themselves, but would also be a significant statement in favour of academic freedom. Since, at present, Soviet policy favours détente and scientific co-operation (at the official level), the chances of a resolute scientist actually getting to the seminar should not be viewed too pessimistically. At the moment the authorities “have to be patient” with visiting scientists, and although, one presumes, the crucial time would be carefully filled with some other function or activity, he is convinced that, with determination, it should not prove impossible.

Meetings normally commence at noon, and details of venue and programme may be obtained from the seminar secretary, Professor Brailovskii. His address is Vernadskogo Prospekt 99, Block 1, Flat 128 (close to the Yugo-Zapadnaya metro station). Unfortunately, as part of the general policy of discouraging participation in the seminar, Professor Brailovskii's telephone was cut off some time ago.

Voronel stresses that such “free contacts” will not only benefit the *refusnik* members of the seminar, eager as they are to maintain an exchange of ideas with other scientists. Such meetings, he says, will benefit the whole concept of scientific exchange with the Soviet Union. All Soviet scientists, not only would-be emigrants, need contacts, scientific freedom, and the free exchange of ideas, within the framework of the whole Soviet scientific community, the seminar is important

FOLLOWING the publication on May 12 of the report of the Court of Inquiry into last year's explosion at the Nypro chemical plant, the inhabitants of the villages around Flixborough are not alone in their misgivings over the report's assertion that "the siting of the works . . ." (in a sparsely populated area) " . . . was fortunate". Residents of the densely populated London boroughs of Ilford, Newham and Barking, who also live in the shadow of a chemical factory which formerly manufactured, and still stores, cyclohexane, are awaiting the outcome of an inquiry into a recent accident at the factory.

The accident, which resulted in the death of a 52-year-old worker, occurred on April 5, 1975, when the plant used in the manufacture of sorbitol exploded in the Ilford factory of Laporte Industries, a British-owned chemical company. The inquiry into the Laporte incident is the first to be ordered by the newly formed Health and Safety Commission whose involvement lends a wider interest to a continuing dispute over the siting of chemical plants that had already developed between the factory management and anxious local residents.

Laporte Industries moved to Ilford in 1961 after taking over the factory from a small pharmaceuticals company and since the move phthalic anhydride, cyclohexane, and sorbitol have, at various times, been manufactured there. Ever since the arrival of the company local people have been concerned about the standard of safety regulations enforced within the factory, claiming that the company has, until recently, acted less than openly with them. In spite of official assurances that everything possible is done to maintain satisfactory safety standards several incidents had occurred before the latest accident.

In 1969 part of the plant used to manufacture phthalic anhydride exploded. After the Flixborough disaster last June it became known that earlier the same year a small fire had broken out in the cyclohexane plant in Ilford. This was the first time that the residents became aware of the dangers posed by

Chemical plants on the doorstep

by Allan Piper

the manufacture of cyclohexane. Although the process was only being operated on a tenth of the scale of that at Flixborough, the Ilford factory is situated in a densely populated area and backs immediately on to a primary school of 650 pupils. Though cyclohexane and phthalic anhydride are no longer manufactured there, both chemicals are still stored there in large quantities.

Local concern led to the formation last year of a tenants' association, the Roding Environmental Safety Campaign (RESC), which is pressing Laporte to provide details of all hazardous processes operated at the factory and wants to see acceptable safety standards implemented at all plants.

But open days held at the factory last year were not reassuring. Neither is the RESC happy about the circumstances under which the cyclohexane plant was permanently shut down last October after a visit by the Factory Inspectorate. In their annual shareholders report, however, Laporte maintain that the closure was purely in deference to the understandable apprehension of local residents and was unconnected with the visit.

The worker who died in April was severely splashed with caustic potash

solution following an explosion in a hydrogen plant used in the manufacture of sorbitol. The Factory Inspectorate are said to have visited plant associated with the hydrogen plant only a few weeks before the accident. Furthermore, the RESC claim to have understood from the company that sorbitol was a "safe" chemical and were not informed that part of the manufacturing process involved some risk.

The RESC has already pressed Parliament for a public enquiry into the running of the factory and a consideration of the siting of dangerous processes in the area. On April 11 Dennis Howell, the Minister of State for the Department of the Environment, expressed a willingness to help but on the question of siting he pointed out that "the Laporte factory was there before the houses and the school were erected, and not the other way round".

The RESC have at least obtained some backing from Redbridge Council who said earlier this month that they would continue to press Michael Foot, the Minister responsible, for a public enquiry into the safety of the works. In the same statement they also referred specifically to enquiries being conducted into the recent accident and said that the Factory Inspectorate had agreed to meet both the Council and the RESC to discuss the inquiry report following its publication.

Whether or not such discussions ever take place will depend entirely upon the Health and Safety Commission: the commission has stated that it would be left to them to "decide whether or not a report is to be published". Though officially they may not allow such a decision to be swayed by matters outside the incident under investigation it is unlikely that they will miss the opportunity to set a healthy precedent. □

as a forum for scientific exchange independent of government and party policy.

The current atmosphere of détente lays considerable stress on scientific contact and exchange. The Soviet authorities, however, says Professor Voronel, wish to monopolise these contacts. Whether the recent flood of scientific and technological cooperation agreements which the Soviet Union has been signing will result in a genuine exchange of scientific opinions and information, not to the benefit of any one country, but to that of science as a whole rests, says Voronel, not with the politicians, but with the scientists. Now is the crucial time, he stresses, for western scientists to establish "new conditions and forms of contact" with their Soviet colleagues. □

Manpower planning and higher education

by Eleanor Lawrence

MANPOWER planning should have a greater part to play in decisions about the future expansion of British universities and polytechnics, according to Lord Crowther-Hunt, Minister of State overseeing higher education.

Speaking at a conference in London last week, he said that "at a time of economic and financial difficulty we need to be more than ever certain that the money we spend is well spent". He emphasised that "it simply will not do to allow universities and polytechnics to produce whatever people they fancy or to relate the number and kind of places they provide to the applicants

that come forward". This was a passive approach which ignored policy variables which were in fact at the disposal of the government.

Undeterred by the admitted lack of success of previous efforts to forecast manpower demand, Lord Crowther-Hunt said that he wished to pursue a "positive approach to higher educated manpower, both to look again at what might be the needs of the economic system and to ask questions not simply about numbers of qualified people but the nature of the qualifications".

The Government could influence the situation in several ways, said Lord Crowther-Hunt. "At the one extreme, student grants and the counselling services of schools can surely affect the demand for places in higher education. At the other a considerable frac-

tion of all graduates end up in public service. It follows that the size of the public sector and the qualifications demand in the public sector will themselves help to determine the number and kinds of graduates we need. It seems to me therefore that it is most unlikely that the best policy for a Government in the long term is simply to observe and to accept whatever is happening", he said.

● Hinting at further economies in the higher education system, Lord Crowther-Hunt dealt with the place of research in the universities in a speech to the Association of University Teachers in Manchester last Friday. About a quarter of university expenditure went into research, he said, which involved about one student in five.

"We all know of postgraduates in our universities who are neither contributing to the advance of worthwhile knowledge nor even adding in any worthwhile way to their qualifications", he said. "Does too much of our effort go into postgraduate work? Should there be a shift of emphasis to undergraduate education and teaching? Just as we have to become more efficient in industry, so do we in education". □

THE theme of this year's International Telecommunications Day, May 17, was "Telecommunications and Meteorology". This was also the theme of World Meteorological Day, March 23. Therein lies a story of real collaboration between two UN agencies which could set a pattern for the future.

Certainly the theme chosen is one that could hardly avoid involving both the agencies concerned—the International Telecommunications Union (ITU) and the World Meteorological Organisation (WMO). The important point is that it was chosen deliberately, the collaboration was intended and the celebrations planned jointly from the start. There are, it is true, a number of factors making it comparatively easy for these two agencies to work together. And each has been in existence long enough to be much more relaxed in its approach and, perhaps for that reason, rather more efficient in its operations than are its bigger brethren.

The trouble is that the large post-war agencies such as the FAO, UNESCO and the WHO tend to regard themselves as autonomous organisations advising—and at times seeming to pressurise—their member governments, rather than servicing them as do the ITU and the WMO. These big boys of the UN family have a certain arrogance that makes close collaboration difficult, not only

Plenty of potential for jojoba oil

by Colin Norman, Washington

It sounds too good to be true. An unprepossessing desert shrub, now growing wild in parts of Mexico and the south-western United States, could, potentially, help save the sperm whale from extinction, rescue a number of Indian tribes from grinding poverty, and supply the automobile industry (among others) with a valuable raw material that is at present unavailable. The catch, though, is that it would take considerable capital investment and several years of effort to convert that potential into reality.

Nevertheless, a committee of the National Academy of Sciences last week enthusiastically urged the federal government to help underwrite the costs of cultivating the shrub on Indian lands. The committee suggested that plans should be set up immediately for establishing 400 acres of plantation a year over a five-year period.

Known as jojoba (pronounced 'hohoba'), the shrub produces peanut-

among themselves but also with the smaller agencies. The latter feel swamped by the huge input that an agency such as UNESCO can allocate to a collaborative project or contribute to a meeting—and irritated by the way in which the same agency may take all the credit, even when the smaller, more expert body has done most of the planning and provided the greater part of the technical expertise.

The agencies do, of course, work well together on specific issues. But in dealing with wider issues—such as the problems relating to the world's water resources, which involves the FAO, UNESCO, the WMO, the WHO, the UN itself and now the United Nations Environment Programme (UNEP)—chaos still tends to reign. The apparently inevitable tendency of any new body to indulge in empire-building, of which the UNEP has in less than two years provided an already notorious example, makes matters worse.

In 1979 or 1980, one understands, it is planned to hold a major UN conference on the role of science in development. Is it too much to hope that, given four years in which to plan it, this may provide a real example of how UN agencies, almost every one of which is concerned in the application of science at one level or another, can collaborate for their own and everyone else's benefit?

from Peter Collins

sized seeds which contain about 50% by weight of a colourless, odourless oil. Its economic potential lies in the fact that the oil is unique among vegetable oils—it closely resembles sperm whale oil and when hydrogenated forms a hard wax which has a number of commercially promising features.

In 1971, the federal government banned use of sperm oil and other whale products in the United States because of the creature's threatened extinction. That move threw the automobile industry into a fit because sperm oil was considered essential for lubricating automatic transmissions. It has unique properties which enable it to withstand high pressures and temperatures,—and frustrating experiences with mineral oil substitutes which have been developed since 1971 attest to its value.

If jojoba turns out to be a good replacement for sperm oil, at the right price, it could rapidly be in high demand. Moreover, if the hydrogenated jojoba wax could be used as a replacement for spermaceti, which is also banned, or carnauba wax, which is now imported from Brazil at record prices, its economic potential would be even further enhanced.

To see whether the material is indeed as promising as people had been claiming, a research project directed by the University of Arizona's Office of Arid Lands Studies and the University of California at Riverside was begun in 1972. To start with, 87,000 pounds of jojoba seeds were harvested from wild shrubs by Indians in California and Arizona, and jojoba oil was farmed out to more than 75 corporations and research institutes for testing. It was the results of those tests, and of parallel tests carried out in Israel, which led to the enthusiasm displayed last week by the committee of the National Academy of Sciences.

The committee's report was intended as a general scientific survey of jojoba oil, and another committee is now taking a close look at the economics and the agricultural aspects of jojoba cultivation. Nevertheless, the report concluded that the evidence is sufficiently promising for the government to subsidise cultivation and an expanded research programme.

Chemical analysis of jojoba oil has confirmed that it is strikingly similar in composition to sperm oil. Both consist of wax esters, with similar chain lengths and an almost identical number of double bonds. And mechanical tests demonstrated that "jojoba oil can duplicate sperm oil performance as a high pressure lubricant".

As for the wax derived by hydrogenating jojoba oil, the committee concluded that it has properties almost identical to those of carnauba wax. At

present, carnauba wax, which is laboriously scraped from the fronds of palm trees, is imported into the United States entirely from Brazil. If hydrogenated jojoba oil could be developed into a domestic wax source, immune from the vagaries of international commerce, US industry would be assured of a continuous supply of uniform quality.

A key factor in the future for jojoba oil, however, is that the shrub could be grown on Indian reservations in the south-western United States, and it could provide a basis for some tribes to become economically self-sufficient. At present, many tribes in the area are living in conditions of extreme poverty.

The problem, however, is that it would be costly to establish plantations, and since it takes on average five years for the shrubs to start producing seeds, return on the investment would be slow.

For those reasons, it is unlikely that industry will move rapidly into jojoba cultivation, and federal government funds will be needed.

According to experience in California, where 34 acres of jojoba were planted in 1974, start-up costs would be between \$1,500 and \$2,800 an acre. The most expensive part of the operation would be clearing and irrigating the land. But, once established, it would cost only about \$100 an acre a year to maintain the plantation and to harvest the seeds. And, since jojoba bushes live for between 100 and 200 years, the initial investment would have ample time to pay off.

Studies have shown that cultivated jojoba bushes would produce, on average, 5 pounds of seeds, and a plantation would yield between 1,000 and 2,000 pounds of oil a year. Since sperm oil

sells at about 40 cents a pound in those countries which still allow it to be marketed, and carnauba wax retails at about \$2 a pound, the committee notes that "it can be seen that returns per acre from established jojoba plantations would be substantial."

Is it possible to predict with certainty that the oil would be in high demand if it were produced? The strict answer is no, but industry has so far shown sufficient interest to justify a qualified yes. Dr Demitrios M. Yermanos, Professor of Agronomy at the University of California, Riverside and a member of the academy committee, noted last week, for example, that jojoba oil has never been available in sufficient quantity for it to be market-tested. But he predicted that once it becomes available in quantity, industry will be very keen to use it. □

correspondence

Naples Zoological Station

SIR,—Some time ago (January 18, 1974) you published an interesting note on the Naples Zoological Station, which expressed the concern of the biological community about the future of the station and considered the importance of its future leadership as well as the question of maintaining international participation in its life and activities.

Since then there have been several changes and we should like to tell you how things stand at present.

After the increase of the annual budgetary support by the Italian government, the new set of statutes has been implemented. Consequently, we have seen the end of the seven-year-long "provisional Administration" and the formation of a new Council of Administration and an Executive Committee. A seat on the new Council of Administration is open to any country or institute that contributes more than £40,000 a year; such participation is seen as one of the most effective ways of strengthening and making more formal the international nature of the scientific collaboration that has been a main feature of the station for more than 100 years. We should very much like to think that Britain will have a seat on the new council.

To complete the new organisation of the station, we now need to appoint a Scientific Council (four members of which must be chosen from among foreign biologists, and one of these four by the International Union of Biological Sciences), and a director. It is

hoped that these appointments will be made shortly.

Yours faithfully,

A. BARLAAM

Naples Zoological Station

Leprosy

SIR,—Most voluntary agencies in Europe engaged in leprosy work are members of the International Federation of anti-leprosy Associations (ILEP) which brings together 22 member-organisations, of which 18 are European. The field of action of the federation extends to some 600 centres or projects in 75 countries afflicted with leprosy. According to the last statistical data available (1973), the federation is helping 1,106,560 leprosy patients, thus representing an important section of the voluntary agencies engaged in the world-wide anti-leprosy campaign. Among all the leprosy patients under treatment in the world, one out of three is aided by the federation. 96% receive domiciliary treatment and only 4% institutional care, as leprosy control is the top priority of the federation, in accordance with the WHO's policy. The total financial help provided by the member organisations is more than £4 million per year. More than 5% of the total budget is spent on research in leprosy (about £360,000 in 1974).

I hope you may consider this as an answer to the following sentence appearing in an article published recently (*Nature*, March 20): "Voluntary agencies in Europe collect more

than £2 million annually for leprosy work, but most is still spent on institutional care".

Yours faithfully,

P. VAN DEN WIJNGAERT

ILEP, 8000 Amiens,
France



A hundred years ago

The subject is treated of under three headings: General Dietetics, Special Dietetics of Health, and Dietetics in Sickness. The author commences with the question—What is the natural food of man? Flesh-eating animals have teeth, jaws, and limbs suitable for capture and tearing, vegetable feeders have bulky viscera, and so on. Applying similar arguments to the human race, "to judge by form and structure alone, the natural food of an adult man must be pronounced to be *nothing*;" from which we must necessarily deduce, as is indicated by other considerations, that man as man assumed his special characters *after* he commenced the employment of instruments for offence and defence. In fact, the developed heel, with which is correlated the non-arboreal habit, is incompatible with the naturally defenceless condition of our species.—from a review of Dr Chambers 'Manual of Diet'. from *Nature*, 12, 64; May 27, 1875.

news and views

Early man in the New World

from G. E. Kennedy

THE question of man's antiquity in the New World has been the source of long and often acrimonious debate. The matter has polarised around two widely differing points of view. An ultra-conservative approach, first developed by Holmes in the 1890s and brought to full culmination by Hrdlicka in this century, was based on two premises: that man was a relatively recent immigrant to the New World and that all Amerindians were of Mongoloid racial type. Hrdlicka was especially effective in destroying any claim to an early arrival of man in the New World and the vigour of his opposition had an almost paralytic effect on the early development of Palaeoindian studies. The conservative viewpoint, scepticism now tempered with careful scholarship, has continued in the work of Haynes, Irwin and others who maintain that empirical evidence of man in the New World prior to about 12,000 BP is very tenuous. The alternate viewpoint accepts considerable antiquity for man in the Western Hemisphere. Workers such as Wormington, MacNeish and Krieger, for example, while properly maintaining that many claims of great antiquity are spurious, have pointed to some early dates which are, in fact, very difficult to dispute.

The evidence of man's occupation of the New World prior to about 12,000 BP falls neatly into two categories: archaeological evidence and human skeletal evidence. Unfortunately, the association of tools and human remains occurs at very few early sites. The Yuha site in southern California, dated at 21,500 BP $\pm$ 2,000 (Childers, *Anthrop. J. Can.*, **12**, 2; 1974) and the Marmes Rock Shelter, in Washington state, dated to about 13,000 BP (Fryxell *et al.*, *Am. Ant.*, **33**, 511; 1968) are two of the very few early sites where such associations occur.

George Carter, whose archaeological work has centred mainly in southern California, is one of the leading proponents of great antiquity for man in the New World; he has suggested that stone tools from the Texas Street site, in San Diego, for example, possibly date to the last interglacial (*Pleistocene Man at San Diego*, Baltimore, 1957). His claims have been widely disputed and most

archaeologists consider that the Texas Street 'tools' were formed by natural rather than human processes. The Calico archaeological site, in the desert east of Los Angeles, has been claimed to demonstrate evidence of human occupation at about 50,000 to 80,000 years ago and dates of 120,000 years ago, based on geological evidence, have also been suggested (Leakey, Simpson and Clements, *Science*, **160**, 1022; 1968). Evidence has been put forward at Calico to support the existence of one and perhaps several hearths deeply buried in an alluvial fan. Though the human origin of the 'hearths' has been questioned the interpretation, as tools, of flaked and chipped lithic material from the site is very difficult to dispute. Conclusions regarding the Calico site should await a more comprehensive study of the lithic materials than has been undertaken so far. Other early sites, from Canada to South America, show artefacts of unquestioned human design in firmly dated contexts. The Lewisville site, in eastern Texas, comprises more than 21 hearths which, in many cases, contain the burnt remains of now-extinct Upper Pleistocene fauna; charcoal from two of these hearths has been dated to more than 37,000 years (Crook and Harris, *Am. Ant.*, **23**, 233; 1958). On Santa Rosa Island, off the southern California coast, burnt mammoth bone has been dated to 29,700 $\pm$ 3,000 (L290R, Broecker and Kulp, *Science*, **126**, 1324; 1957). Other material, obtained from a fire area on the island was reportedly beyond the range of radiocarbon dating (UCLA 749, Berger and Libby, *Proc. natn. Acad. Sci. U.S.A.*, **56**, 1678; 1966). A recently reported site from the Old Crow River basin in north-eastern Canada has yielded a worked caribou tibia dated to 27,000 $\pm$ ^{+3,000}/_{-3,000} (Irving and Harington, *Science*, **179**, 335; 1973). One of the most indisputable of the palaeoindian tool sites is in the Ayacucho Valley of Peru; here, in a deposit underlying a level with a radiocarbon date of 19,600 BP $\pm$ 3,000, MacNeish has found stone tools in association with the bones of Pleistocene fauna (*Scient. Am.*, **224**, 36; 1971). On the basis of the early occurrence of this "core tool tradition" in South

America, MacNeish has suggested that man may have entered the New World as early as 100,000 years ago.

In the analysis of human skeletal material, the field of Amerindian palaeontology is still in its infancy, in spite of nineteenth century origins. Very little early human material is known and of that material provenance and associations are sometimes unsure. With a few notable exceptions none of the very early material has been completely described and without exception none of this early material has been analysed within the statistical framework of population theory. Such treatment, in a comparative context, is vital if we are to gain objective insight into the origins and relationships of the earliest Amerindians.

Of the human material that is available, the child's remains from Taber, Alberta may have present claim to the greatest antiquity; stratigraphical evidence suggests that the site is more than 37,000 years old and may be as much as 60,000 years old (A. Stalker, *Am. Ant.*, **34**, 425; 1969). The racemisation dating technique has been of considerable importance in placing many specimens, long undated, in a chronological framework. The earliest of the racemisation dates has been obtained from the 'Del Mar' skull; this nearly complete cranium from southern California has been dated to 48,000 BP (Bada *et al.*, *Science*, **184**, 791; 1974). A frontal fragment from the same area has been dated to 44,000 BP and a potentially important group of post-cranial material has been dated at 28,000 BP (*ibid.*). This latter material, however, recovered 49 years ago, has not yet been cleared from its matrix. The 'Los Angeles Man' cranium has been dated with both radiocarbon and racemisation and these dates are in close agreement: >23,600 in the first case (Berger *et al.*, *Contr. Arch. Res. Fac.*, No 12, University of California at Berkeley, 1971) and 26,000 in the latter (Bada *et al.*, *ibid.*). The clear antiquity of Los Angeles Man makes the unaccountable loss of the associated post-cranial material very regrettable. The Laguna skull, also from the southern California coastal region, has been dated to 17,150 $\pm$ 1,470

(Berger *et al.*, *ibid.*).

Although there is no question of the Mongoloid affinities of the modern Amerindians the origins of the earliest groups are not as clear. Some anthropologists consider that the Mongoloid populations of Asia are among the most recently developed of the major human racial groups. Coon and Birdsell, for example, would argue that the Mongoloids developed, as a population, not more than 10,000 years ago. If this is true, then obviously the earlier New World immigrants must have had non-Mongoloid affinities. Birdsell, Hooton, Howells and others have, in fact, detected possible Caucasoid elements in the remains of some early Amerindians and have linked these with Upper Pleistocene populations in eastern Asia; Birdsell has used the term 'Amurian' for these Asian groups. The question of the population affinities of the earliest Amerindians is a complex one and the answer must await further data from both Asia and the New World.

Oddballs and galaxy formation

from James Binney

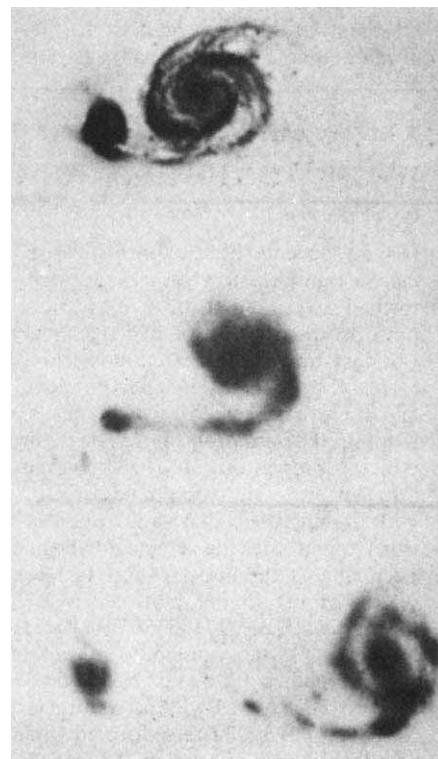
THERE seems to be no limit to the number of weird objects one can turn up in the sky. We now have catalogues compiled by Zwicky, Vorontsov-Velyaminov and Arp, containing over ten thousand peculiar extragalactic objects. These range from almost stellar, highly luminous emission line objects to groups of distorted, apparently interacting galaxies. Many of the objects identified as peculiar on optical plates turn up also as unusually strong emitters in other ranges of the electromagnetic spectrum. Undoubtedly these objects would well reward greater study. Indeed three recent papers suggest that they may be able to teach us something about one of the greatest enigmas of modern cosmology: the formation of galaxies.

Freeman and de Vaucouleurs (*Astrophys. J.*, **194**, 569; 1974) suggest that pairs of an irregular galaxy and a spheroidal galaxy could be produced by the collision of spiral galaxies with an hypothesised intergalactic cloud of neutral hydrogen (see *Nature*, **254**, 181; 1975). Freeman and de Vaucouleurs suggest that the Universe may be filled, not necessarily uniformly, by a few hundred clouds of neutral hydrogen per massive galaxy. If the

radii and masses of these clouds lie in a narrow region around 10^5 light-years and 10^9 solar masses they claim one can account for the observed density of spheroidal-irregular galaxy pairs in terms of the compression and fragmentation of the gas involved in the collision of the gaseous part of a spiral galaxy with one of these clouds. Stars formed from this gas would form the irregular or ring galaxy while the stellar component of the spiral galaxy would pass on as a spheroidal system.

This links with the work of Oemler who has concluded from a study of 15 rich clusters of galaxies (*Astrophys. J.*, **194**, 1; 1974) that there are three basic types of rich clusters: spherical ones, like the cluster Abell 2199, which contain an irregular giant galaxy at the centre and are rich in elliptical galaxies, clusters rich in lenticular galaxies and spiral rich clusters. Oemler's work tends to confirm the suggestion of Gunn and Gott (*Astrophys. J.*, **176**, 1; 1972) that the spiral rich clusters are ones in which the general cosmic expansion, though slowed by gravity, has not yet been reversed, whereas the clusters rich in lenticulars are ones where recollapse has occurred and a substantial fraction of the spiral galaxies initially present have been stripped of their disk component in interactions with an intergalactic medium. Could this intergalactic medium consist of the gas clouds of Freeman and de Vaucouleurs? Is it the mass of these clouds which binds the galaxies into a cluster in spite of the very high velocities these galaxies appear to possess?

Another quite different interpretation of some of these multiple systems of interacting peculiar galaxies is argued in a research note by Vorontsov-Velyaminov (*Astr. Astrophys.*, **37**, 425; 1974). Vorontsov-Velyaminov believes he has identified a number of systems caught actually in the act of breaking up into two or more parts, or 'gemination' as he calls it. The figure for example is taken to show three stages in the ejection of a satellite galaxy from a late-type spiral galaxy. Though this example could perhaps be more easily understood in terms of satellite capture for which numerical models by Toomre and others exist (*Astrophys. J.*, **178**, 623; 1972), others of Vorontsov-Velyaminov's specimens could well represent small groups of galaxies forming from a large cloud of hydrogen. A fragmentation process of this type has been suggested by Casini *et al.* (IAU meeting, Trieste, September 1974) in relation to Markarian's very similar groups of galaxies.



Proposed stages in ejection of a satellite galaxy from a late-type spiral galaxy; from Vorontsov-Velyaminov, *Astr. Astrophys.*, **37**, 425; 1974.

All this tinkering with the population of dwarf galaxies does not of course directly help us to understand the more fundamental formation of giant galaxies like our own. Nothing daunted by the failure of cosmologists to come up with a satisfactory mechanism for triggering the formation of condensed objects in an expanding Universe, Meszaros (*Astr. Astrophys.*, **38**, 5; 1975) has explored the possibility that a primordial population of black holes of about solar mass might have precipitated the much later collapse of galactic masses. He finds that if the total mass of black holes in the present-day Universe were between one and ten times the mass contained in visible galaxies, the statistical fluctuations in the number density of black holes in the early Universe may have caused perturbations in the overall matter density of the Universe to grow from the end of the first 10^{-4} s of our history. These black holes would now be clustered around galaxies in enormous numbers (about 10^{12} around the Milky Way) forming a massive halo of the type whose existence has been suspected on other grounds (Ostriker and Peebles, *Astrophys. J.*, **186**, 467; 1973). Unfortunately the detection of these black holes is well nigh impossible and the physics underlying theories of their formation rather doubtful.

The real problem of galaxy formation remain very much unsolved. The

greatest difficulty is that we still have no idea what induced the formation of

How to study the birth of galaxies using radio-astronomical techniques

by John Gribbin

IF you accept the standard picture, galaxies and clusters of galaxies were formed by condensation from a more uniform distribution of hydrogen gas. But just how hydrogen clouds transformed into galaxies is far from clear, and there has seemed little chance of making the situation more clear by direct observation. Now, however, Sunyaev and Zel'dovich have come up with a suggestion that radio observations might provide a clue to events occurring at the epoch when galaxies were forming in the Universe (*Mon. Not. R. astr. Soc.*, **171**, 375-379; 1975).

Some of the principal questions which are far from being answered are listed by the two Soviet astronomers: Were globular clusters formed first and later joined into galaxies? Did the first step consist of separation and condensation of giant gas clouds (with masses in the range 10^{13} - $10^{16} M_{\odot}$) which later disintegrated into galaxies, globular clusters and individual stars? At what redshift z (relative to us) did this occur? And what were the density and temperature of the gas clouds from which galaxies formed?

In principle at least, some of these questions might be answered by radio-astronomy studies not hopelessly more sophisticated than those of the present day. One approach would be to search for the redshifted 21-cm hydrogen line emission from the epoch just before galaxies were formed.

Sunyaev and Zel'dovich consider the case of spherical galaxies with mass $3 \times 10^{14} M_{\odot}$ and diameter 2 Mpc, separated by 30 Mpc. Making reasonable assumptions about the proportion of neutral hydrogen, H I and He I, and taking the diameter of a cloud just before stars formed as also being typically 2 Mpc, it turns out that the hydrogen line should still be seen as an emission line, even with a redshift of 5-10, if at least half the proto-galactic material was in the form of hot gas ($T \sim 7,000$ K). The increase in temperature of the observed line over the background is, however, only expected to be some 7 K, for an observer co-moving with the proto-galaxy.

But to an observer on Earth the line will be redshifted to 100-200 cm wavelength, a region where the overall background has a brightness temperature ranging from 20 to 200 K. Is it sensible to expect to be able to detect the redshifted hydrogen line

above this background? The answer depends, of course, on just how many proto-galactic clouds there might be at these large redshifts in each solid angle of sky subtended by the observing telescope. Sunyaev and Zel'dovich conclude that no more than 200 protoclusters might be visible over the whole sky at any one wavelength, and that "observations with a variable wavelength are essential, both in order to augment the number of protoclusters observed and also to distinguish them from sources of different type with continuum spectra".

They also suggest still more complicated experiments, but this one test is likely to be enough to tax the ingenuity of radio astronomers at present. Still, the possible results would seem to merit some effort being made. As Sunyaev and Zel'dovich say, "these observations are very difficult and substantial improvement of existing equipment will be needed to fulfil the task, but the importance of the problem seems . . . to warrant discussion in order to attract the attention of experimentalists".

● **One in a million.** Meanwhile, a reminder to galaxy hunters that not all of the peculiarities of unusual astronomical objects result from physical processes hinting at new universal laws, and that coincidences do happen, has come from a study by de Vaucouleurs and de Vaucouleurs of NGC985—a ring galaxy with a Seyfert nucleus (*Astrophys. J. Lett.*, **197**, L1; 1975).

If ring galaxies do form when normal galaxies collide with intergalactic clouds (as Binney discusses above), and if, as seems likely, some (and perhaps all) normal galaxies experience Seyfert outbursts, it is plausible that the formation of the ring in NGC985 and the presence of Seyfert activity are completely unrelated. De Vaucouleurs and de Vaucouleurs suggest that the probability of a randomly chosen Sa-Sc spiral having encountered an intergalactic gas cloud in the past 5×10^7 yr (so that the ring is still visible) is about 10^{-4} , and that the probability that the nucleus of a giant spiral is seen today in the Seyfert stage is about 10^{-2} . That makes NGC985 literally a galaxy in a million.

the first bound objects in an expanding Universe. One suspects that the origin of these local inhomogeneities in the structure of the Universe will be understood only when we know why the Universe is so remarkably smooth and homogeneous on a large scale and a major effort is now going into the possibility that this isotropy is the result of quantum effects back in the period when the Compton wavelength of an elementary particle was comparable with the radius of the then visible Universe. The other urgent task in cosmology is to understand how in the more recent past great masses of gas collapsed to form galaxies and clusters of galaxies. This task is particularly exciting because there is every reason to believe that we should be able to actually see this happening by looking out into distant space. What we require are detailed models of the collapse to enable us to identify a nascent galaxy when we see one.

Specific response of *Drosophila* cells to heat shock

from Benjamin Lewin

WHEN larvae of *Drosophila melanogaster* are subjected to a heat shock, usually a rise in temperature to 37 °C from the usual 25 °C, a change in the pattern of puffing is seen in the salivary gland chromosomes; preexisting puffs regress and new puffs appear at several, specific sites. The same response is produced by treatment with respiratory inhibitors and occurs during recovery from anaerobiosis. The switch to puffing at these bands presumably represents the expression of new gene functions and, because of the different treatments which elicit it, may perhaps constitute some generalised response to certain environmental abuses of *Drosophila* larvae. The specific puffing pattern can be provoked by heat shock of isolated salivary glands and so must be autonomous. It is not known what functions it represents; but the limited number of bands that is involved and their coordinate expression in response to more than one treatment of larvae or excised tissues suggest that this may be a useful system for investigating genetic control and defining the number of functions in individual bands.

Two recent series of experiments exploit the remarkable observation that heat-shocked tissue culture cells of *Drosophila* seem to display the same response as whole larvae or isolated salivary glands. The cultured cells in both sets of experiments are derived from Schneider's S2 line,

originally grown from mixed early embryonic cells, and therefore unfortunately not of well defined phenotype. But the cells' apparently autonomous response implies that the results of experiments with them may be representative of the *in vivo* gene expression of *Drosophila* larvae.

A study of the messenger RNA present in normally grown and heat-induced cultured cells was recently reported by Spradling, Penman and Pardue (*Cell*, **4**, 395-404; 1975). The poly(A)-containing mRNA of the polysomes of these cultured cells shows a very broad size distribution on sucrose gradients, similar to that seen with many cultured mammalian and insect cells. When this RNA is hybridised *in situ* with salivary gland chromosomes, it binds to many loci, apparently representing at least 50 bands on the four chromosomes; in addition there is intense binding at the chromocentre. Of course, it is not surprising that many genes in euchromatin should be expressed; some bands, about a dozen, are more heavily labelled than most and these are seen more clearly by using lower concentrations of the labelled mRNA. This reduction in concentration leaves the chromocentre still heavily labelled, however; the chromocentre seems to include two types of heterochromatin: α -heterochromatin which consists of satellite DNA and is under replicated in the formation of polytene chromosomes, and β -heterochromatin, about which less is known. Since satellite DNA seems to be inert in transcription, these results suggest that α -heterochromatin may contain genetic material that codes for mRNA. Another implication of these results is that a comparatively small number of bands is expressed in the cultured cells, certainly fewer than (say) a hundred. Yet estimates of complexity made from the reaction between mRNA and cDNA or isolated nonrepetitive DNA suggested the expression of a much larger number of genes, of the order of 2,000 (cited in Bishop *et al.*, *Nature*, **250**, 199-203; 1974). Kinetic analysis suggests that most messengers represent genes in nonrepetitive DNA; and genetic analysis suggests that each band specifies a single genetic function. This discrepancy is therefore difficult to resolve at present if all the messenger species in the population are able to hybridise *in situ*.

A drastic change occurs in the mRNA when the cultured cells are shifted to 37 °C. Within an hour, the broad distribution on a sucrose gradient is replaced by four distinct peaks, in a somewhat similar overall size range. When the poly(A)-containing mRNA of the heat-shocked cells

is hybridised *in situ* with salivary gland chromosomes, it reacts with only a small number of bands, those that are puffed during heat shock in the larva or excised tissue. This suggests that the same switch in gene expression occurs in the cultured cells as in the intact tissue. The most heavily labelled band is 87C1, and other labelled bands include 63C, 67B, 87A, 93D, 95D. Although very similar to the heat-shocked puff pattern, the hybridisation pattern is not identical; some bands that puff in larvae, 33B, 64F, 70A, do not hybridise specifically with the heat-shocked mRNA, and band 85A binds mRNA after heat shock but does not puff in larvae. Whether this represents a genuine difference in gene expression between cultured cells and salivary glands or is rather a consequence of different assay systems is not known; however, the same repression of previously functioning bands and almost identical expression of new bands is produced by heat shock in both cases.

Changes in protein synthesis

A start towards identifying the functions of the heat-shock puffs was made last year by Tissieres, Mitchell and Tracy (*J. molec. Biol.*, **84**, 389-398; 1974) when they reported that heat shock causes changes in the pattern of protein biosynthesis; synthesis of most proteins is much reduced but synthesis of a small number, about six, is induced. This provides an obvious correlation with the changes now observed in mRNA synthesis. Tissieres *et al.* observed that the principal induced protein has a size of about 70,000 daltons and corresponds to some 20% of the newly synthesised protein. Since the heat-shocked puff that they observed at 87B accumulated newly synthesised RNA the most intensely, they suggested that this protein may be coded by a gene in the 87B band.

Using the Schneider S2 culture line, McKenzie, Henikoff and Meselson (*Proc. natn. Acad. Sci. U.S.A.*, **72**, 1117-1121; 1975) now report that the same changes in protein synthesis, followed by SDS gel electrophoresis, are exhibited in response to heat shock. After incubation at 37 °C for 50 min, the proteins induced in the heat-shocked cells comigrate with those induced by temperature shock of isolated salivary glands. The most prominent band again has a size of some 70,000 daltons.

A large shift in the polysome profile took place upon heat shock. At 25 °C, the polysome distribution shows a peak at 12-13 ribosomes per message; but after incubation at

37 °C for 10 min these polysomes disaggregate. After 30 min at the higher temperature, larger polysomes form, with 20-30 ribosomes on each messenger. At 50 min, this is the type of polysome observed on a gradient. Addition of actinomycin does not prevent the disaggregation but does inhibit appearance of the new (larger) peak, suggesting that these polysomes include the messengers newly synthesised in response to the heat shock. When the RNA from the heat-induced polysomes was isolated, it gave a single peak on a sucrose gradient, corresponding to a length of about 3,300 nucleotides. Presumably this peak includes several messenger species. This length of mRNA is sufficient to code for protein of up to some 120,000 daltons, and therefore can certainly be viewed as a possible messenger for the 70,000 dalton protein. When used for *in situ* hybridisation with salivary gland chromosomes, the RNA of the heat-shocked polysomes predominantly labelled band 87B of the third chromosome; however, in a note added in proof, McKenzie *et al.* conclude that this labelled material may in fact correspond to band 87C1. Bands 87A and 93D both also are labelled in this hybridisation, as is the chromocentre. The coincidence between the heavy synthesis of the 70,000 dalton protein and the heavy labelling of 87C1 lends support to the idea that this band may include the gene for this protein.

The identification of an individual band with a single protein, and the availability of the messenger RNA intermediate, in principle offer an opportunity to investigate in one instance the relationship between band and gene. Although genetic analysis suggests an equation between a band and a genetic function identifiable by mutation, which implies that only a small part of the band is used to code for mutationally visible protein, this does not formally exclude models postulating that other DNA in the band may code for proteins not identifiable by lethal mutations. The heat-shock system may offer a valuable independent opportunity to investigate the function of the band at the molecular level. If the functions of the proteins coded by the heat-shock puffs can be identified, this system also may allow the coordinate control of separated genetic functions to be studied since it comprises a small number of proteins whose synthesis readily can be switched on and off. And of course, it remains to be seen exactly how the expression of these functions enables the organism to withstand heat shock. □

Structure of a lectin

Crystallographic results

from C. C. F. Blake

ALTHOUGH the major effort in protein crystallography is at present centred on enzyme structure, structural studies on certain non-enzyme proteins may provide information of somewhat wider biological importance. One such group of proteins is the lectins. These molecules, found largely in plants, and particularly in seeds, have a number of interesting and unusual biological properties that derive from their ability to interact with cell surfaces. Their characteristic property is the ability to agglutinate erythrocytes, sometimes in a blood-group specific manner. Other cells may also be affected and most interestingly some lectins are preferentially able to agglutinate cells that have been transformed by viruses, carcinogens or radiation. In addition certain lectins are mitogenic; that is, they are able to stimulate the transformation of lymphocytes from small resting cells to large actively growing cells that may ultimately undergo mitotic division. The specific inhibition of the activity of many lectins by simple sugars has led to the conclusion that lectins bind specifically to saccharide chains on the surfaces of cells. The study of the structure and activity of these proteins could lead to an understanding of the molecular basis of their sugar specificity and the mechanism of their action on cells, which could in turn provide an insight into the structure and behaviour of the cells themselves.

Because of its availability and ease of extraction the most extensively studied lectin is concanavalin A from the jack bean. It is also one of the more interesting members of the group, because in addition to being haemagglutinating, it is also mitogenic and capable of specifically agglutinating malignant cells. The concanavalin A molecule is composed of polypeptide chains that have a molecular weight of 25,500; below pH 6 the molecular species is a dimer, and above pH 6.5 it is a tetramer. The protein apparently binds to glucosyl and mannosyl residues at the non-reducing end of oligosaccharides, and it is most potently inhibited by α -methyl-D-manno- and glucopyranosides. Like other lectins concanavalin A requires the ordered binding of manganese and calcium ions before it can exhibit its sugar binding capacity.

Since concanavalin A was crystallised by J. B. Sumner as long ago as 1919, it is not surprising that it has more

recently been the subject of extensive X-ray diffraction studies. The general features of the molecular structure were reported independently three years ago by Edelman's group at the Rockefeller University (Edelman *et al.*, *Proc. natn. Acad. Sci. U.S.A.*, **69**, 2580; 1972) and by Hardman and Ainsworth (*Biochemistry*, **11**, 4910; 1972) at the Argonne National Laboratory. Recently a series of four papers has come from the Rockefeller group which reports the complete amino-acid sequence of the protein and a definitive description of its molecular structure (Wang *et al.*, *J. biol. Chem.*, **250**, 1490; 1975; Cunningham *et al.*, *ibid.*, **250**, 1503; 1975; Becker *et al.*, *ibid.*, **250**, 1513; 1975; and Reeke *et al.*, *ibid.*, **250**, 1525; 1975).

The X-ray studies have been carried out at 2.0 Å resolution on the tetrameric form of the protein with both types of metal ion bound. The overall shape of the monomer is best described as a flat-based dome with dimensions of 42 Å × 40 Å × 39 Å. Its structure is dominated by two large, entirely antiparallel β sheets. One of these sheets, containing six strands, forms the entire base of the dome and is, unusually, almost lacking the twist normally seen in β sheets. The second β sheet, forming the central slice of the dome, lies at a shallow angle to the first sheet, with its seven strands twisted through 90°. The top of the dome is formed by a number of loops, mainly derived from the immediate N-terminal and C-terminal parts of the polypeptide chain. The quaternary structure of the protein involves two distinct types of subunit interaction, both largely involving the flat β sheet. Interactions of one type cause the monomers to associate in pairs with equivalent strands at the edge of the flat β sheet forming antiparallel hydrogen bonds, to give dimers that contain a 12-stranded β sheet. The second type of interaction involves the face-to-face opposition of these 12-stranded sheets from two dimers, contacts being made through both hydrophobic and ionic side chains that point outward from the sheets. Interestingly the domains of the immunoglobulins, to which the lectins have sometimes been compared, have a similar β -box structure and associate through interactions very like the dimer-dimer interactions in concanavalin A (for references see *Nature*, **253**, 158; 1975). But a more closely related protein is the thyroxine-binding plasma protein, prealbumin, which has both the same type of tertiary structure and subunit interactions (Blake *et al.*, *J. molec. Biol.*, **88**, 1; 1974).

In each subunit the Mn^{2+} and Ca^{2+} ions are located in a surface cavity near

the apex of the dome, only 4.6 Å apart. Each ion is in an octahedral environment composed of four protein ligands, two of which are shared, and two water molecules. The geometry of the binding sites seems to explain the ordered binding of the ions in terms of manganese binding at a proto-binding site, causing conformational changes that complete the site and at the same time form the neighbouring calcium-binding site. About 20 Å from the metal positions is a deep cavity between the two large β sheets in the monomer that seems to be the saccharide binding site. It seems to be composed of two distinct subsites: a deeper one that is predominantly hydrophobic and a more hydrophilic subsite nearer the surface of the molecule. But although this site is occupied by the heavy atom labelled inhibitor, β -(O-iodophenyl)-D-glucopyranoside, other simple sugars that specifically inhibit the protein cause the crystals to dissolve or lose their diffraction patterns. Although this behaviour indicates that the binding behaviour of the protein is altered by crystallisation, Becker *et al.* argue that the alteration is probably a marginal change to the true saccharide binding site in the cavity, rather than the blockage of the true site that is really elsewhere on the molecule. Clearly, this proposal must be tested by either further crystallographic studies or by appropriate solution studies such as NMR, because it is essential to the understanding of the protein's sugar specificity and its interactions with cell surface glycoprotein receptors.

NMR used to study rates of change of conformation

from J. Feeney

A good deal of useful information can be obtained from measurements of the enhanced proton NMR relaxation rates of the water in aqueous solutions of metalloenzymes containing paramagnetic ions. In the past these methods have been used by Cohn, Mildvan, Koenig and their coworkers to determine binding constants for the paramagnetic ion-protein complex and the nature of their ternary complexes with ligands. From studies of the frequency dependence of the relaxation enhancements it is often possible to deduce the number of water molecules in the coordination sphere of the metal, and detailed information about the ligand exchange rates and correlation times of the interactions. When Barber and Carver (*J. biol. Chem.*, **248**, 3353;

1973; *Can. J. Biochem.*, **53**, 371; 1975) applied these techniques to Con A they were surprised to observe large time-dependent changes in the water proton relaxation enhancement after Mn^{2+} was added to a solution of Con A.

Maximum enhancement was noted immediately after the addition and then the enhancement decayed to a reduced value with an apparent half life of ~ 20 minutes which strongly suggested that a slow conformational change was taking place. They were able to show subsequently that while the occupation of the transition metal binding site does not change the conformation of the demetallised protein, the addition of Ca^{2+} ions to the Con A- Mn^{2+} complex and of α -methyl-D-mannosides to the Con A- Mn^{2+} - Ca^{2+} complex perturbs the protein structure.

Grimaldi and Sykes (*J. biol. Chem.*, **250**, 1618; 1975) have recently developed an elegant stopped-flow NMR method which allows them to follow the kinetics of the various conformational changes induced in Con A by the ordered binding of Mn^{2+} , Ca^{2+} and α -methyl-D-mannoside from measurements of the time-dependence of the water relaxation enhancement under controlled conditions. The sensitivity limitations of the NMR technique often militate against successful kinetic applications but in this case where the intensity of the large water signal is being followed this is not a problem. An advantage of using NMR for such studies is that the NMR parameters for the species involved in the kinetic process contain information about molecular parameters such as number of ligand sites, ligand exchange rates and correlation times for the interaction.

Three separate conformational states of the protein could be discerned in the kinetic experiments and it was possible for Grimaldi and Sykes to outline the order of the steps in the binding process. For example, the conformational changes induced by adding Ca^{2+} to Con A in the presence of Mn^{2+} resulted in intensity changes of the water resonance which could be analysed according to first-order kinetics. From the dependence of the observed rate constants on the Ca^{2+} concentration it was deduced that the Ca^{2+} binds rapidly to the Con A- Mn^{2+} complex producing a decrease in relaxation enhancement and this is followed by a subsequent conformation change giving a further decrease in enhancement. The decrease in enhancement probably results from restricted rate of access of the water molecules to the bound Mn^{2+} following the large conformational change. When Ca^{2+} dissociates from the conformationally changed protein the water proton relaxation enhancement remains constant, indicating that the protein retains its conformation.

Grimaldi and Sykes have also examined the kinetics of binding the sugar α -methyl-D-glucoside to Con A in the presence of Mn^{2+} and Ca^{2+} . It should be mentioned that there has been some controversy concerning the sugar binding site in Con A. Measurements of the paramagnetic contribution to relaxation rates of carbon-13 nuclei in α - and β -methyl D-glucopyranosides bound to Con A (Brewer and co-workers, *Biochemistry*, **12**, 9448; 1973) indicate that the sugars are much closer to the manganese ion (mean distance ~ 10 Å) than was suggested by earlier X-ray diffraction studies (20 Å).

In the kinetic studies of Grimaldi and Sykes the initial binding of sugar was considered to be at a site well removed from the metal binding sites and it does not influence the water signal. There is, however, a subsequent slow conformational change after the sugar binding which increases the water proton relaxation enhancement. This is followed by a further slow conformational change which is essentially the same as that resulting from Ca^{2+} binding in the absence of sugars.

3 . . . 2 . . . 1 . . . 0?

from C. H. L. Goodman

ONE-DIMENSIONAL conductors are suddenly the fashionable field of solid state research, and a flood of short but weighty notes in *Physical Review Letters* and *Solid State Communications* warns of massive presentations and theses in the pipeline. It also heralds organic compounds with conductivities like those of metals, and even a completely new type of superconductor.¹

Electrical conductors normally encountered are relatively isotropic, conducting to a more or less similar extent along any of their three dimensions. Perhaps the only reasonably common material showing pronounced anisotropy is graphite, which in well crystallised material, has an electrical conductivity within the two dimensions of its hexagonal sheets 10^4 greater than perpendicular to them. Such 'layer lattices' have been the subject of a great deal of research over the past ten years. Fairly recently however there has been a sharp switch of attention to 'one-dimensional materials' (composed of parallel long chain molecules).

There are three main materials being studied at present: TTF:TCNQ (tetrathiafulvalene: tetracyanoquinodimethane), the polymer of sulphur nitride (SN)_x, and KCP (K₂Pt(CN)₄Br_{0.3}·3H₂O). All show high electrical conductivity along the chain axis, and rather small conductivity perpendicular

to it. They look metallic to the eye, but as might be expected show marked optical anisotropy with polarised light.

Until recently the most dramatic research has been associated with TTF:TCNQ. Heeger and his group at the University of Pennsylvania believed they had discovered a possible organic high temperature superconductor² — certainly with a room temperature conductivity of 10^3 (ohm cm)⁻¹ rising to nearly 10^5 (ohm cm)⁻¹ just below 60 K, this material is a most highly conducting solid and has been much investigated³. The sharp transition to a much more resistive semiconductor at 58 K was interpreted as resulting from a Peierls instability — a type of crystallographic distortion which is expected in these materials⁴ but which might be avoidable by disordering the material in some way or by modifying the structure. Thus IBM workers have recently reported⁵ the transition being reduced to 40 K with the selenium analogue, TSeF:TCNQ.

The platinocyanide, KCP, also shows high electrical conductivity rising sharply as temperature is reduced, but this material (and its chloride analogue) again undergoes a transition to a high resistivity solid. Its study has been bedevilled by its chemical instability: the water molecules which stabilise the structure can get lost well below 100 °C, and in any case the correct structure has only recently been established^{6,7}.

Probably least understood is (SN)_x; it is one-dimensional⁸, though with helical rather than linear chains; it is metallic and conducts well even at low temperatures⁹. But what has particularly excited interest is that it has recently been found to be a superconductor¹, albeit with a very low transition temperature (0.26 K), the first quasi one-dimensional superconductor to be discovered. It is interesting that the discoverers refer to the weak inter-chain coupling as a possibly important factor.

The key to all these one-dimensional materials in fact almost certainly lies with what are usually termed the van der Waals bonds holding the chains together in the crystals. These bonds are not too well understood and some degree of electron orbital overlap may be involved. It is probable however that crystal growth presents a related but more immediate problem, perhaps a real practical barrier to progress. One cannot but be suspicious that 'one-dimensional' crystals appear to be capable of being 'fattened up' during growth, whereas a truly one-dimensional crystal should not be able to nucleate on its sides and should persist in (linear) growth with the

diameter of the seed (assuming that the latter can be obtained). To me the observed 'growing-out' means either that structural imperfections are present due to forced growth or (and it may amount to the same thing) that chain branching can somehow be induced during growth. If this view is correct the most perfect one-dimensional crystals will be those which are most acicular, not the more equiaxed shapes which have been prepared, after much effort, to give large area specimens for physical measurement.

Finally if van der Waals bonds are so important should not someone be looking at zero-dimensional crystals — those held together only by van der Waals forces (or at least what are usually thought of as them)? These crystals by definition would not be metallic, of course, unless 'intercalated' (if that were possible) but their transport properties could be interesting. If a suggestion is in order, GeI_4 and SnI_4 with their brilliant vermilion-red hue do have a most attractive appearance!

- ¹ Greene, R. L., *et al.*, *Phys. Rev. Lett.*, **34**, 577 (1975).
- ² Jacobsen, C. S., *et al.*, *Phys. Rev. Lett.*, **33**, 1559–62 (1974).
- ³ Coleman, L. B., *et al.*, *Solid State Commun.*, **12**, 1125 (1973).
- ⁴ Sen, P. N., and Varma, C. M., *Solid State Commun.*, **15**, 1905 (1974).
- ⁵ Engler, E. M., and Patel, V. V., *J. Am. Chem. Soc.*, **96**, 7376 (1974).
- ⁶ Deiseroth, H. J., and Schulz, H., *Phys. Rev. Lett.*, **33**, 963 (1974).
- ⁷ Williams, J. M., *et al.*, *Phys. Rev. Lett.*, **33**, 1079 (1974).
- ⁸ Boudouelle, M., and Michel, P., *Acta Cryst.*, **A28**, S199 (1972).
- ⁹ Walatka, V. V., *et al.*, *Phys. Rev. Lett.*, **31**, 1139 (1973).

Science and religion

from a Correspondent

For the past three years there have been a number of informal consultations between scientists who have been concerned to relate their scientific knowledge and modes of study to their religious faith and practice. Those involved decided in 1974 that their deliberations should be more widely known and from April 10 to 12, the 'Science and Religion Forum' was inaugurated, at a meeting at van Mildert College, Durham, devoted to 'The Problem of Consciousness'.

THE problem was introduced by a paper on "reductionism in biology" by A. R. Peacocke (University of Cambridge), who distinguished between different forms (ontological, methodological and epistemological-linguistic) of 'reductionism'—roughly, the analysis and explanation of entities in terms of their component units, for example explaining all biology in terms of physics and chemistry. Some forms of reductionism would be generally agreed as simply required methodologically by scientific

research, but others represent a more general position which can determine attitudes to the relation between consciousness and brain states. Mary Hesse (University of Cambridge), expanded this discussion by describing certain non-additive, non-reducible situations in the quantum physics of particles. Higher-order relations can emerge in complex (for example living) systems which, not in any mysterious metaphysical sense, constitute a kind of logical irreducibility. For example, the analogy of programming from computer science could be valuable in providing a non-reductive valid way of talking about consciousness.

T. Appleton, of the University of Cambridge, gave an account of studies on communication and language at various levels in the biological world and, in particular, described recent work on primates, which shows evidence of a higher level of consciousness, based on their ability to communicate through American Sign Language, than previously thought from studies of verbal communicating abilities.

Howard Robinson, of Liverpool University, outlined, for the benefit of a predominantly scientific audience, the state of the mind-body problem in contemporary philosophy which has concerned attempts to make materialism philosophically respectable—attempts which though widely canvassed, have made only a limited number of converts and which Mr Robinson rejected. Some form of materialism was, in fact, that adopted by a number of those who joined in a general discussion session which inevitably focused on the sensitive area of concepts such as 'soul', 'immortality' and 'personal identity' in relation to scientific, philosophical and theological ideas.

Professor John Bowker (University of Lancaster) described the development of religious consciousness in terms drawn from systems analysis and information process. He drew attention to the extent to which religions function as bounded systems of information process, in which resources are made available to human beings for the construction of a life-way from birth to death—and traditionally in religions, through death as well. 'Religion' and 'science' were originally undifferentiated, emerging from the general endeavour of men to defend and maintain the continuity of their life-way in relation to the limitations which circumscribe it. The sense of God is effective and dynamic as an informational resource in the construction of human life: to take an example, it would thus be possible to interpret Jesus as the totally God-informed person retrieving in the scan of every situation the cues through which the 'sense of God' is stored in

human brain-behaviour, and thus himself becoming a resource for the construction of a religiously-informed human being.

At very short notice, the Bishop of Durham, John Habgood, spoke on "religion-and-science and the church". He stressed the need for philosophical sophistication in the science-religion debate; for reconciliation between the idea of continuity assumed by scientists and that of discontinuity implicit in the beliefs of ordinary Christians; and for man's responsibility for nature (including the ethics of research) to be a principal concern of those present.

Two-step transfer reactions between heavy ions

from P. E. Hodgson

LAST year some measurements were made of the differential cross section of the $^{48}\text{Ca}(^{16}\text{O}, ^{15}\text{C})^{49}\text{Ti}$ reaction at 56 MeV by the Argonne group (Kovar *et al.*, *Phys. Rev. Lett.*, **33**, 1611; 1974). This is a strange reaction: at first glance it looks like a one-nucleon transfer reaction, but closer examination shows that the transferred 'nucleon' must carry two charges. The only possible mechanism is thus a series of nucleon transfer reactions equivalent to a transfer of two protons minus one neutron. This might be expected to be very unlikely, but in fact it is found that the cross section of the reaction to the ground state of ^{49}Ti is comparable to that of normal one-nucleon transfer reactions.

In recent years there has been much interest in multistep contributions to nuclear reactions. These are recognised to be of two types: first those that can proceed through the excitation of the target or the residual nucleus by inelastic scattering (*Nature*, **251**, 188; 1974) and second those proceeding by a series of particle transfer processes. Calculations have been made in a variety of ways for both processes, and in many cases it has been found that the inclusion of multistep contributions greatly improves the agreement between theory and experiment.

In most of the reactions studied so far both these processes could conceivably contribute, and it is sometimes not clear which is the dominant one, except in reactions involving highly collective nuclei which are very easily excited by inelastic scattering, so that the first process dominates. The special feature of the $(^{16}\text{O}, ^{15}\text{C})$ reaction is that it must proceed by successive particle transfer, and so it furnishes an excellent case to test the multiple particle transfer theories.

These calculations are exceptionally complicated because in heavy ion reactions it is not sufficiently accurate to make the zero-range and no-recoil approximations that greatly simplify the calculations for light ion reactions.

The Texas group of Tamura, Udagawa and Low have however found ways of carrying out the full calculation for heavy ions without loss of accuracy and sufficiently economically for them to be done in a practicable time on a fast computer. They have written computer programs to do both types of multistep calculation for heavy ions, and have now applied one of them to the $^{48}\text{Ca}(^{16}\text{O}, ^{15}\text{C})^{49}\text{Ti}$ reaction (*Phys. Rev. Lett.*, **34**, 30; 1975).

They considered two possible reaction mechanisms, one-neutron pickup followed by two-proton transfer and *vice versa*, and added their amplitudes to obtain the total cross section. Written out in full, the two reaction mechanisms are $^{48}\text{Ca}(^{16}\text{O}, ^{17}\text{O})^{47}\text{Ca}(^{16}\text{O}, ^{15}\text{C})^{49}\text{Ti}$ and $^{48}\text{Ca}(^{16}\text{O}, ^{14}\text{C})^{50}\text{Ti}(^{14}\text{C}, ^{15}\text{C})^{49}\text{Ti}$. The intermediate nuclei ^{47}Ca and ^{50}Ti were assumed to be in their ground states and in the first reaction the ^{17}O nucleus could be either in its $5/2^+$ ground state or its first $1/2^+$ excited state, leading respectively to the $1/2^+$ ground state and $5/2^+$ excited state at 0.747 MeV in the final nucleus ^{49}Ti , both of which were observed. In the second reaction the ^{14}C nucleus remained in its ground state.

As the experimental cross sections are structureless and of low accuracy it is not possible to make a good test of the calculations solely by the fit to the angular distribution. It is necessary to try to reproduce the absolute magnitude of the cross section, and this is particularly important because one of the exceptional features of this reaction is

the high value of the cross section to the ground state of ^{49}Ti .

To obtain an absolute cross section all the parameters of the calculation must be fixed beforehand by reference to other reactions. This was done in the present case by fitting available data for the one-neutron transfer reaction $^{48}\text{Ca}(^{16}\text{O}, ^{17}\text{O})^{47}\text{Ca}$ and the two-proton transfer reaction $^{48}\text{Ca}(^{16}\text{O}, ^{14}\text{C})^{50}\text{Ti}$ which are the same or similar to those involved in the postulated mechanisms for the $^{48}\text{Ca}(^{16}\text{O}, ^{15}\text{C})^{49}\text{Ti}$ reaction.

The results of these calculations are shown in the figure, and it is apparent that the absolute magnitudes are correctly given, and that the shapes of the calculated angular distributions are consistent with the experimental results. It is particularly gratifying to find that the relatively high cross section of the reaction to the ground state of ^{49}Ti is correctly given. The relative magnitudes of the two reactions are attributable to complicated interferences between the contributing processes.

More precise data are needed before we can learn more about the details of this reaction, and other possible contributing processes must be considered, but this pioneer calculation of a multistep particle transfer process shows that these reactions are now amenable to quantitative calculations, and it is likely that many more such calculations will be made in the future.

Engine with a solid working fluid

from Robert W. Cahn

THE faintly surrealistic title of this reportage denotes a faintly surrealistic concept. All 'heat engines' hitherto have been designed to operate with working fluids: the fluid may be steam, petrol vapour/air mixture or air (in the Stirling engine), but all depend on cycles involving simultaneous changes of temperature and pressure. Now it is proposed to design an engine in which changes of temperature and stress are applied to a metallic spring, which constitutes the working 'fluid'.

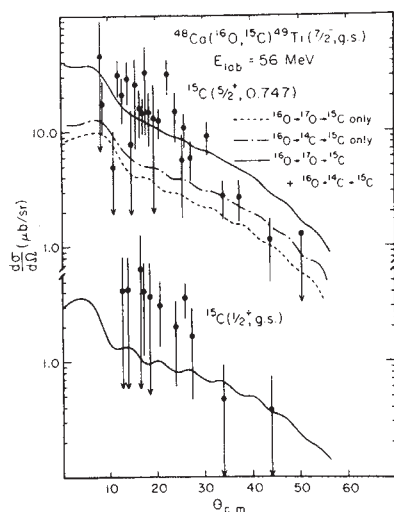
The idea (which is not altogether new) is revived in a paper by Tong and Wayman (*Metallurgical Transactions*, **6A**, 29; 1975). The spring has to be made of one of the alloys—a select band—which exhibit shape-memory. The peculiar properties of these alloys have featured in these pages before (*Nature*, **219**, 895; 1968; **224**, 844; 1969). Essentially, such an alloy can be 'imprinted' with a suitable shape, such as that of a spiral spring, by plastic working followed by heat treatment. It can then be pseudo-plastically deformed at or near ambient temperature: it will retain the new shape until it is heated

to a higher temperature (typically 100 °C) and it will then return to its imprinted shape, even against a substantial restraining force seeking to prevent it. It can then be cooled back to ambient temperature without further distortion. Tong and Wayman point out that this sequence can form the basis of a heat engine to utilise solar heat or waste heat. They do not consider the engineering design (though they refer to a properly engineered prototype recently constructed at the Lawrence Radiation Laboratory) but they do attempt to evaluate the ideal cycle efficiency of such an engine as a function of various metallurgical variables, and conclude that an ideal efficiency of about 20% should be quite feasible.

Part of the charm of the idea is that the critical temperatures of the alloy, which define the upper and lower temperature limits of the cycle, can be varied within wide limits, both by going to different alloy systems and by small changes of composition within one system. Nearly equiatomic Ti/Ni alloy (Nitinol) is probably the most promising—and most thoroughly investigated—material; it has a virtually unlimited tolerance of mechanical cycles without fatigue.

The engineering aspects of a solid-state engine will require a good deal of design ingenuity. Ideally, it would seem, a simple engine should incorporate two or more springs (or other more elaborate configurations), so that one could be heated up while the other gives up its heat to a sink; heat transfer during both heating and cooling would need to be rapid if the engine is to be anything more than a mechanical tortoise. Presumably a heat pipe to earth would be necessary. An engine of this type might, for instance, be designed to pump irrigation water in deserts, using solar energy.

Shape memory is merely one of four closely linked metallurgical phenomena: thermoelastic martensitic transformations (progressive, thermally reversible shear transformation); pseudoelastic behaviour (large strains, much larger than normal elastic strains, brought about by shear transformations that are themselves reversible with stress); shape memory effect; and a two-way shape memory effect, which involves shape changes induced by temperature changes alone, without intervention of stress. Some alloys show most of these, some show only one; some show an effect in single crystal form, others will do so in the normal, polycrystalline form. The tangled connections between the various effects have been clearly analysed in an important series of papers by Delaey, Krishnan, Tas and Warlimont (*J. mater. Sci.*, **9**, 1521, 1536, 1545; 1974): the authors list all the alloys that have



Differential cross section for the $^{48}\text{Ca}(^{16}\text{O}, ^{15}\text{C})^{49}\text{Ti}$ reaction to the ground and first excited states of ^{49}Ti compared with exact coupled reaction channel calculations. The contributions of the two postulated reaction mechanisms are shown separately and added together.

been found to evince any of these effects and analyse the structural, mechanical and thermodynamic features that underly them. These papers are essential reading for anyone who would like to have a go at a solid-state engine. Delaey and his colleagues have provided the steam tables, as it were, of the solid-state engine.

Tong and Wayman have recently published another paper (*Acta Met.*, **23**, 209; 1975) in which they analyse some of the thermodynamic variables that predispose an alloy to thermoelastic or shape memory behaviour. One interesting conclusion, which is given an interpretation in terms of the 'quasi-chemical' bond-energy approach, is that an ordered alloy (such as FePt) has a lower latent heat of transformation, and is more easily able to undergo thermoelastic transformation, than the same alloy in an ordered form. This seems to be a generally valid conclusion.

The solid-state engine may well be able to compete with other physical devices, with or without radiation concentrators, for extracting power from solar radiation. According to Brinkworth (*Solar Energy for Man*, Compton Press, 1972) such devices have ideal efficiencies in the range $\frac{1}{2}$ –1% (for simple thermoelectric generators) to as much as 30% for thermionic generators with concentrators. The latter are likely to be even more expensive on capital than a solid-state engine, and do not directly generate motion. The engine would seem to deserve some further investigation, which will certainly require the collaboration of metallurgists and mechanical engineers.

Successful quake prediction made

from Peter J. Smith

THERE is now ample evidence that some small to moderate earthquakes are immediately preceded by a period during which the seismic velocity ratio (V_P/V_S) in the vicinity is anomalously low. This effect was first observed by Kondratenko and Nersesov (*Tr. Inst. Fiz. Zemli Akad. Nauk SSR*, **25**, 130; 1962) in the Garm region of the USSR for events in the magnitude range 4–5; but similar V_P/V_S changes have since been detected in respect of magnitude 2–3.3 earthquakes at Blue Mountain Lake (New York State), the magnitude 6.4 San Fernando earthquake of 1971, the magnitude 5 Bear Valley (California) earthquake of 1972, two shallow earthquakes in Japan and several other events in various parts of the world. The importance of this phenomenon lies in its potential for earthquake prediction, the more especially as the duration

of the precursory V_P/V_S anomaly seems to be related to shock magnitude. But can the potential be converted to practice? In each of the examples cited above, the precursory behaviour was detected by data analysis subsequent to the event. Aggarwal *et al.* (*J. geophys. Res.*, **80**, 718; 1975), however, are now able to report that they have made a genuine and successful prediction.

It was Aggarwal and his colleagues who carried out the original study of the 1971 earthquakes at Blue Mountain Lake, thus becoming the first (*Nature*, **241**, 101; 1973) to confirm the Soviet observations of ten years before. The larger events in the 1971 series were preceded by V_P decreases of 15–20% and V_S decreases of 5–10%. Subsequently, however, the region became relatively quiet seismically until on 14–15 July 1973 the calm was shattered by two magnitude 3.6 and four rather smaller earthquakes. In response to this renewed activity, Aggarwal *et al.* immediately (15–16 July) set up a system of portable seismographs and strong motion accelerographs to supplement (for six weeks) the permanent BML station.

During the first third of this period, the recording system indicated an average S wave–P wave travel time ratio (t_S/t_P) of 1.73. Over the few days following 30 July, however, t_S/t_P decreased to about 1.5. In 1971 the corresponding 'normal' value of t_S/t_P had been about 1.75 and reductions comparable to that now observed had preceded by several days' earthquakes of magnitude 2.5–3.3. Aggarwal and his colleagues thus took the t_S/t_P decrease of 31 July–2 August 1973 to herald a shock of comparable magnitude. On the night of 1 August they therefore predicted that an earthquake of magnitude 2.5–3.0 would occur within a few days.

The maximum magnitude of the apparently impending event was estimated from the inferred spatial extent of the t_S/t_P anomaly. In contrast with the situation in 1971, the most distant (common) station in 1973 remained unaffected and thus presumably lay outside the anomalous zone. Assuming the size of the anomalous region to be directly proportional to the magnitude of the responsible event, and comparing the 1973 data with those of 1971, the upper magnitude limit of the expected earthquake was about 3. The minimum magnitude was obtained by estimating the minimum duration of the t_S/t_P anomaly. The 1971 results had showed that, following its initial rapid decrease, t_S/t_P had returned to its normal value rather more slowly and had reached it about one day before the earthquake occurred. As by 1 August 1973 t_S/t_P showed no sign of increasing, precedent suggested that the expected earthquake was unlikely to occur for

at least two days, making a total t_S/t_P anomaly time of at least four days. And according to the previously established magnitude–precursor time relationship (Scholz *et al.*, *Science*, **181**, 803; 1973), this would correspond to a magnitude of 2.5.

The earthquake which occurred close to the edge of Blue Mountain Lake on 3 August 1973 had in fact a magnitude of 2.6. Aggarwal and his colleagues are thus the first to predict successfully the place, time and size of an earthquake in the United States and the first to make practical use of precursory seismic velocity changes. Moreover, in their method the precursory interval (whose onset may be detected but whose duration cannot be known until t_S/t_P returns to normal just before the impending event, which may be too late) may be used for predictive purposes before it is complete. If, as seems likely, the size of the anomalous region associated with an impending earthquake is a unique function of the shock magnitude, it follows that once the anomaly appears (and assuming it grows rapidly to its full extent) its spatial dimensions should give magnitude directly. The magnitude can then be fed into the known magnitude–precursor time relationship to determine how long the anomaly will persist and thus just when the earthquake will occur. In short, in any particular case prediction may not have to await the gradual approach of t_S/t_P towards its normal value; valuable time may be gained by making the critical measurements before the rise in t_S/t_P even begins.

Obviously, for this method to succeed it is essential that the size of the anomalous zone be measured reasonably accurately; and here there are difficulties. For one thing, the size of the zone may vary with time, which would complicate the supposed relationship between zone size and magnitude. The temporal characteristics of this relationship are not yet known, although there is evidence that if the anomalous zone grows it must grow relatively rapidly. Second, it would clearly be advantageous to use explosive sources to determine precursory velocity changes and thus define the extent of the anomalous region. But in this case care must be taken to ensure that the waves actually penetrate the zone of anomaly. Aggarwal *et al.* show that large changes in V_P and V_S are not observed at shallow depths (less than 0.5 km at BML) for near-horizontal wave paths. This could mean either that significant velocity anomalies do not exist at these depths or that the cracks there are predominantly horizontal. Either way, some sort of anisotropy is implied; and this is likely to complicate the mechanics of the prediction method.



Manpower supplement

In this issue we put together a number of articles on different facets of scientific manpower. This can in no way be regarded as a comprehensive survey; rather we have considered a number of subjects and of countries and have taken one person's view in each case. The treatment is very largely journalistic—if that means that our analyses lack the background of years of experience it also means that they lack much self-congratulation and a sense that all is necessarily for the best. For in some ways the purpose of this supplement is to warn that the question of the use of scientific manpower is increasingly not one which can be ignored. It is becoming abundantly clear that the system by which schools supply universities and polytechnics which supply schools, industry, government and themselves is not automatically self-regulating.

At the heart of manpower issues are several contradictions:

- Scientists or their representatives are increasingly looking for life-long tenure, although science itself proceeds more by revolutions and perpetual rejuvenation.
- The waning appeal of science to the young is widely believed to be largely because science is highly specialised and dissociated from human dimensions and therefore unattractive, but this is just at a time when some of the questions that are being asked of science are simple, stimulating, strongly related to human needs and highly multidisciplinary.
- Bad news about employment prospects can affect the choice of career of a prospective scientist six or more years before employment prospects become relevant.
- At a time when the techniques of manpower planning are being criticised for coming up with the wrong answers, the British Department of Education and Science apparently intends to use the manpower-planning approach in formulating some of its policies for higher education.
- Academic life is supported in great part by the taxpayer and yet intervention by government in university affairs is all but unthinkable.
- Scientists, particularly in government and industry, often experience a conflict of loyalties between their employer and the wider, often international, cause of science.
- Students, for various reasons, can occasionally get

hooked in large numbers on subjects such as astronomy in which employment prospects are poor and universities often powerless to do much except absorb all-comers.

Perhaps one of the most tricky problems of manpower use is the all-growing-old-together syndrome. This can be seen around the world in two totally different situations—defence establishments and new universities. In the 1940s, in response to the demonstrable success of scientists in the Second World War and the emergence of the Cold War, many new establishments were formed and many old ones recruited in large numbers. Likewise in the 1960s in Britain (and later in some other parts of the world) many new universities were built and absorbed vast numbers of young researchers as teaching staff. The degree of homogeneity in both these groups is undoubtedly higher than elsewhere, but homogeneity coupled with a growing seniority is not necessarily the best of environments for research. And recruitment within a narrow temporal band often means that people are taken on simply because they are around rather than because of any intrinsic merit they possess.

There are many other topics worth pursuing—brain drains, the PhD in industry, retraining programmes, the research scientist as school teacher, are but a few. The only things that can be said with much certainty about the scientific profession at present are that a young man entering at 21 can not expect an uninterrupted ride to 60, and that the scientific community is going to hear more and not less of the word manpower in the next few years.

D.D.

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Excess demand in the graduate employment cycle

John Hall

After the lean years of the early 1970s the traditional employment of science graduates is picking up, but the result is likely to be a shortage because the graduates have found that non-traditional jobs can be quite attractive.

THREE years ago, anyone embarking on an account of how scientific manpower problems were affecting British university science departments would have had a field day. The big twelve companies who normally take most of the country's new science graduates had developed cold feet because of an acute economic recession, and the last people they needed on their payrolls were recently qualified specialists who knew next to nothing about industry and would take at least two years to start paying their way. Some companies pared their intake dramatically, others simply said they would take no chemists, or chemical engineers or metallurgists at any price. Alarming noises about the growing pool of unwanted science graduates were to be heard from universities like Manchester, and nobody dissented too vigorously from the view that there would never again be a return to demand of the mid-1960s for chemistry graduates.

Up and down the country, careers masters read their newspapers and sixth formers listened to hard-luck stories from 'old boys' who were selling vacuum cleaners door-to-door because there were no more laboratory jobs available and, shortly, entrants were avoiding the worst-affected courses in such numbers that chemistry professors began to look nervously over their shoulders in case anyone noticed that there were not all that many people to lecture to any more. (The staff-student ratio was a nonsense in an area which had an important research function, they implied, and in any case, as one professor pointed out in a letter to *The Times*, the laboratory assistants on the payroll made the picture look bleaker than it really was.)

Now it is the turn of the science-based industries to sweat things out, and university chemistry and chemical engineering departments are in the position of supplying an increasingly scarce product in a seller's market. The better graduates are being offered a choice of up to six jobs this year, and in 1974 chemical engineering graduates at the University of Manchester Institute of Science and Technology (UMIST) were accepting first appointments at around £3,000 a year. One started at

£5,000. The only people who seem surprised by the turn-around are the unfortunate recruiting officers who closed industry's doors so recently and announced that the golden days were over. Now they have the doors open again, and they are explaining that they had never meant that they should be taken so literally when they said what they did. But nobody (in the universities at least) is shedding too many tears over industry's plight, because there is a fairly unanimous opinion that the wound was self-inflicted. What is more, many departmental heads and appointments board people went to great pains in 1971 and 1972 to point out to bashful employers the likely effects of over-reacting, and now those effects are to be observed, precisely as predicted, they can be excused a little self-congratulation.

In hard times, the universities said, industry would clearly be making some cuts in its recruitment programmes. If those cuts were reasoned and moderate, there would be a corresponding feedback to the schools, where there would be a gradual and appropriate decrease in the number setting out to be chemists (or whatever). According to this picture, industry's decreasing demand and the universities' decreasing supply of scientists would describe similar trajectories on a graph of the affair, levelling off to run in parallel towards an infinitely distant point of mutual satisfaction.

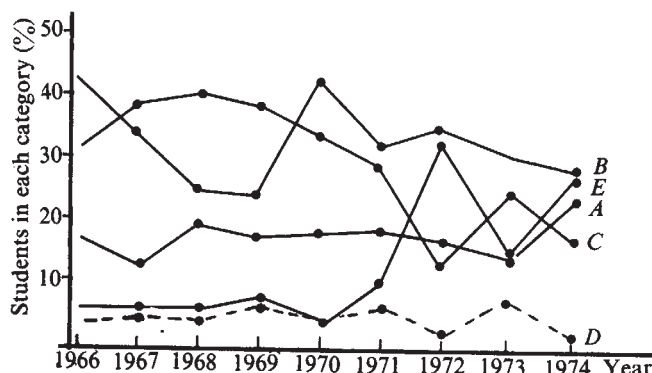
An alternative approach was for industry to base its recruitment plan on that year's trading figures, without reference to much else. In this situation you cry out for all the manpower you can lay hands on when business is going well, and when the books begin to look bleak you reduce recruitment drastically, or if it is a really bad year you cut it out, period. Now, the news gets back to the schools that there is simply no way in which anybody is going to make a living as (say) an industrial chemist. The vacuum cleaner salesman confirms what the careers master has read and, instead of getting a tapering off of supply, the universities find that the bottom drops out of the market in the appropriate subject. This would be an admirable approach if it took twelve months to train a chemist from his entry into the lower sixth form at school. As it happens, it takes five years for subject options made at school to be translated into terms of graduate supply, so if industry were to take this line then it would be fairly crucial that it be absolutely certain of its manpower requirements five years ahead.

In the event, science-based industries proved to be no better than anyone else at forecasting needs five years in advance, and as a result it is now in the market for people whose scarcity is a direct result of its own short-term manpower policies. Because of the time lag between the industry's statement of its manpower requirements (or non-requirements) and the effect of that declaration on graduate output, the graph shows two curves in constant oscillation about an axis which they both cross about once in five years. Industry pays through the nose when the scientists' supply curve is at its nadir, and the demand curve peaks. When it happens the other way round, the scientists pay for it.

Responses

As university students and teachers are thinking beings, and not the mute commodities which the supply and demand equation supposes, however, they are able to make adaptations to reduce their vulnerability, and since they received their last fright from industry about four years ago there have been at least two changes which strengthen their position. Industry's recruitment cut-back made many science-trained graduates look for jobs in areas which were, traditionally, beyond both

Fig. 1 First destinations of graduates of the University of Manchester. A, Teacher training; B, postgraduate work; C, chemical or allied work; D, 'still looking' six months after graduation; E, commercial or other work.



their area of interest and their grasp. They moved, often out of sheer desperation, to the professions which offered a kind of institutionalised security and which had been historically the preserve of the arts graduate—that is, to the Inland Revenue, to insurance, business management, accountancy, and even

Table 1 Possible employment of new chemical engineering graduates in 1978

Public service and education		25	
Public Service			==
Civil Service, local authority, river boards, and H.M. forces	20		
Education			
Technical college, etc. (not teacher training)	5		
Industrial and commercial		440	
Oil and chemical industry		180	==
Heavy chemicals	72		
Fine chemicals	30		
Petroleum	40		
Plastics	15		
Industrial gases	15		
Soap and detergents	8		
Engineering		120	
Contracting	60		
Chemical plant manufacture	25		
Steel and other metals	28		
Air conditioning	7		
Other manufacturing		60	
Food	20		
Fibres and textiles	15		
Paper and board	10		
Others	15		
Civil Engineering, building contractors, and so on		5	
Public utility, NCB, AEA		40	
Coal	12		
Other mining products	12		
Water and effluent	12		
Atomic energy	4		
Accountancy		15	
Banking and insurance		5	
Other commerce		15	
Others		5	
Total entering permanent employment in this country		470	
Employed overseas (on permanent or short term basis)		40	
Returning home overseas or otherwise not available for employment		40	
Failing to keep in touch or taking more than 6 months to find permanent employment (as in recent surveys)		100	
Higher education and training (including teacher training)		180	
Total output of graduates required		830	==
This total is based on a distribution of home to overseas students of 730 home to 100 overseas			
1975 intake to university chemical engineering departments required to provide this output		950	==

The Institution of Chemical Engineers, which is keen to see a restoration of equilibrium in the demand and supply of new graduates, conducted an investigation leading to an estimate of the demand for graduate chemical engineers in 1978 (published in *Chemical Engineer*, March, 1975). A report presented to the institution's Careers Committee was prepared, by way of a preliminary estimate, by combining first-employment surveys and assessments by industry and Institution members. The resulting Table above is believed to be a conservative estimate of the possible destination of new graduates and shows that the universities should be producing about 830 new graduates each year. Allowing for the usual wastage rate, the intake to universities should be in the order of 950. The actual intake could be as much as 400 short of this target.

law. These new directions, although often taken as makeshifts, have been found by science graduates to be surprisingly pleasant alternatives to the accepted routes through the research and development or academic career structures—so much so that although the necessity for science graduates to seek non-traditional alternatives as their first-destination employment has now been largely removed, there has not been a corresponding switch back to the traditional jobs. In effect, it has been established that a scientific education may be regarded as a non-vocational training for a variety of non-scientific careers.

This response to a scientific manpower surplus was foreseen as long ago as 1961, when a government report (*The Long Term Demand for Scientific Manpower*) welcomed the possibility of scientists moving into non-scientific careers. A surplus of scientists over immediate demand for employment, said the report, "should make possible a rational, as opposed to an emergency use of scientific disciplines. It should mean that at long last we shall have a supply of qualified manpower with a scientific training for management, administration and the professions generally, in addition to those who up to the present have been drawn inevitably into vocational employment. We do not doubt that scientific education will adjust itself to this new prospect; and that in the same way as only a proportion of those trained in the classics and history have expected to find employment in their own fields of study, an increasing proportion of those trained in specialised scientific disciplines will obtain employment outside them. We think that both science and the nation will benefit from this adjustment."

What the student employment applications for 1974 and this year show is that the trend foreseen in the 1961 report as a response to a manpower surplus situation is continuing at a time when the conditions which gave rise to it have subsided. A second change which has occurred as a result of the falling demand for scientists at the beginning of the decade is that course content has changed (and in some cases entry requirements) in order to secure students with a broader initial outlook and a broader and more flexible operational capability on graduation. The notion that it is possible to predict when a student enters, the market forces which will prevail when he leaves university has in many places been abandoned; the aim is rather to give the student a hard core of indispensable knowledge in his special area, and to offer a range of options which will make him sufficiently versatile to take advantage of such employment opportunities as present themselves, whatever they may be.

Trends

Apart from making the science graduate a more adaptable individual than he was formerly, the cut-back in demand has also tended to make him think in a very positive way about the direction he wishes his career to take. Whereas during the 1960s anyone going to university to read chemistry accepted without much thought about the matter that he would work as a chemist in industry, in government research or in a university, that assumption is no longer made today. Appointments board officers at Cambridge, Manchester and Imperial College, London agree that the changed circumstances of the science graduate in the early 1970s have produced a situation in which the student has become accustomed to making an active decision about the way his working life will start. They also agree that, although this may be bad news for ICI, or Shell, or for the government centres which automatically expected a visit from the best students every year, it is good news in an educational (or existentialist) sense that people are exercising a more conscious choice about their personal destinies.

On the same level, there is also a feeling that student intake to science has not taken such an upward turn as employment vacancies because of a positive decision among school leavers that science is directly responsible for many of society's ills, and that they will not be a party to any extension of the technological nightmares which beset the Western world. The universities tend to point out, without any sense of historical

conviction, that scientists are the only people who are ever likely to make the bad dreams go away, which is rather like saying that peace can only be enforced by the military. And they try to court the science-shy with courses on environmental studies, pollution control and energy sources—which is progress, of a kind.

What universities think

Specific information about science students, courses and employment trends at Manchester, Cambridge and Imperial College can be summed up as follows:

● **Cambridge.** Science courses are generalised until the third year, when a specialist option is taken. The number taking chemistry is so small that professors are starting to worry about the security of their salaries and employers are falling over themselves to get at the few who emerge with chemistry degrees. In the past, the pressure has been on people who are doing fairly well at their subjects to pursue them to the bitter end; that is, to take their higher degrees and go into academic work. But this year it is noticeable that the academic world is not proving as attractive, which is hardly surprising when final-year students looking for openings in university teaching see nothing more rosy than appointments on a one-year tenure. (Professor A. B. Pippard is reported to have said that there is no future in the universities for 90% of the science students who are there now, and that looks like an optimistic estimate.) The consequences of the last cut-back are to be seen in student career choices (accountancy, business and so on) and in the attitude of employers from these areas, who are prepared to regard science as a general training in thinking and, therefore, as an acceptable entry qualification for a variety of non-scientific jobs. Buoyant areas are electronics and communications. General prognosis for the science subjects: an upturn in intake and in employment opportunities, but never a return to the levels of the 1960s.

● **Imperial College, London,** prides itself on having a finger on the pulse of industry, and for this reason claims that it never had any real problem placing its graduates although there was a distinct drop in the number of applicants for chemistry courses last year. Maybe it never had much trouble in its placings because it has a tradition of sending people to a wide range of careers (up to 20% make for areas like banking and insurance). They report that since people tried teaching as a life-raft during the lean years it has become a popular career choice on its own merits. The demand for chemists and chemical

engineers is well up, and Imperial College says it did not really notice a serious decline in the demand for chemists at any stage. (In the 1970–72 period when the national unemployment figure stood at 16%, Imperial College's graduate unemployment was less than 0.5%.) In its best years, the chemistry department had up to 1,000 applicants for 95 places. This fell in 1974 to 220-odd applicants for 60 places, but this year applications are up 30% on last year. Imperial College sells its graduates by emphasising project work, individual initiative in problem solving, and practical laboratory experience. It also makes a good showing on integrated studies like the history and philosophy of science and languages.

● **Manchester.** The university hopes the decline in chemistry applications has bottomed out and is on the increase again. This year there are 60 final-year chemists, compared with 80 to 95 in the best years. There is a demand for Manchester's chemists, who now do a course of two years' hard-core chemistry, followed by a year of options which include environmental chemistry, psychology, management and liberal studies. Flexibility is the keynote. The metallurgy department, with less than half the number of students it had in 1972 (and with the national total of metallurgists lost running at 250 a year), is in a position to take its pick of the jobs offered. The subject's unpopularity is partly caused (according to Professor K. M. Entwistle) by "a reluctance to inject courses with an element which lets the students see that we recognise the responsibilities of science; that we see science as more than an intellectual exercise." Remedy: broader-based courses including economics, accounting and social science. This year's applications are up by more than 50% to something over 200. Image is also a problem in the chemical engineering department at UMIST, where it is feared that anything with the word 'chemistry' in it is equated with the word 'poison'. A broader course is seen as part of the solution again; this time it is subjects like pollution control, energy sources and foreign languages as a relief from the narrower mainstream of chemical engineering. A second brain drain is forecast when the Americans come to Britain to recruit for their energy-crisis programme, and since there is already a shortfall in chemical engineers produced, as against numbers required, they will become an even scarcer commodity than they are this year, when they can take their pick of jobs. Five years ago they were next to unemployable. Every other applicant for chemical engineering in the UK applies to UMIST, and what he gets for his money is an unsurpassed pilot plant to practice on, and a course with an entirely elective third year.

Signs of shifts in employment patterns

Colin Norman

After a period of rapid growth, enrolment in higher education in the United States is levelling off. The result is likely to be an increasingly bleak academic job market for scientists and engineers with PhD degrees and the trend has major implications for the nature of graduate education.

LAST month, a committee of eminent astronomers issued an unprecedented appeal for graduate education in astronomy to be cut back because of dismal employment prospects for new PhDs. Unless enrolment in graduate astronomy departments is substantially reduced, the committee said, the number of young scientists leaving universities in the United States with freshly minted PhDs in astronomy and closely related subjects could soon outstrip the number of available jobs by about six to one. Already, the committee noted, there are some 200 astronomers

holding temporary postdoctoral appointments who have little chance of getting permanent jobs in astronomy.

Although extreme, the manpower situation in astronomy reflects problems which are being encountered in some other fields of science. In fact, if most projections are at all accurate, there is likely to be a growing imbalance between the supply of scientists and engineers with PhD degrees in a variety of disciplines and the number of jobs for which their training is directly suitable.

That prediction is based on two major trends affecting the manpower situation for PhD scientists and engineers. First, federal expenditures in most areas of science and technology have recently levelled off or even declined, and there is unlikely to be much real growth in support of basic research in the next few years. And, second, after a period of rapid expansion, higher education has entered a period of retrenchment. Overall enrolments in graduate and undergraduate departments have

been declining and there is little chance that they will grow much over the next 20 years.

Although the reduced enrolment will tend to curb growth in the supply of scientists and engineers, it will also have a marked impact on the academic job market for PhDs—the declining growth rate in higher education will result in a similar reduction in new teaching positions in the universities, so that scientists and engineers emerging from graduate schools will increasingly have to look outside academia for employment. Superimposed on that trend, however, is the fact that prospective federal support for a few activities—such as energy research and development and possibly cancer research—is likely to create high levels of demand for scientists and engineers with both first and higher degrees in a few selected disciplines. In fact, according to some estimates, there may be severe shortages of people with some specific skills and that could distort the overall manpower picture drastically.

Those trends hold interesting implications for higher education and it should also be noted that they are both outside the direct control of the universities. The slowdown in overall growth is largely a consequence of the fact that the postwar 'baby boom' has now passed through higher education so that there is likely to be no growth in the college-age population for at least the next two or three decades. And the increasing support for energy research and development is coming directly from the federal government.

Boom and bust in the 1960s

In view of distortions created by previous federal programmes, college administrators are likely, however, to view with mixed feelings the prospective rapid increase in support for energy research. The situation which led to the call for cutbacks in enrolments in graduate astronomy courses is instructive in that regard. The call came from a special committee of the National Academy of Sciences, which met under the chairmanship of Leo Goldberg, Director of the Kitt Peak Observatory.

Like most other sciences, support for astronomy expanded rapidly during the early 1960s as part of the frantic post-Sputnik build-up of science and technology in the United States. But, just as young people began pouring out of the universities with PhDs in astronomy in the early 1970s, support for astronomy began to decline. The figures speak for themselves.

The number of PhDs employed in astronomy increased by 111% (from 623 to 1,313) between 1970 and 1973, and last year alone 180 astronomy PhDs were awarded. There are now about 900 students enrolled in graduate astronomy courses who will be looking for jobs in the next five or six years, and adding to the problem is the fact that astronomy has traditionally attracted PhDs from closely related branches of physics. Yet the committee estimates that there will be no more than 200 jobs available in the next five years.

At the root of the problem is the fact that funding for astronomy in general has been declining—federal support shrank from \$227.3 million in 1968 to \$186.8 million in 1972, the committee estimates. And there are scant prospects of any increase in the years ahead since the bulk of the funding now comes from NASA; with the shuttle taking up an ever-increasing share of the space budget, there is likely to be little money to spare for expanding space-borne astronomy, at least until the early 1980s.

Although it can be argued that astronomy is something of a special case, since job openings are largely confined to one sector—higher education itself—the situation there dramatically underscores one basic factor in supply and demand for highly trained manpower. The education process is so lengthy that periods of high demand and plentiful supply of trained individuals are often completely out of phase. Moreover, the trends which have led to the bleak manpower situation in astronomy—rapid expansion, followed by cutbacks, followed perhaps by constant or at best slowly increasing support—are evident in most scientific disciplines.

Overall, US expenditures on science and technology expanded rapidly during the early 1960s, but began to level off in about 1968. In fact, in terms of constant dollars, the total support for research and development declined between 1968 and 1971 before picking up slightly. The same pattern is evident in the total support for all higher education—the share of the gross national product devoted to it doubled between 1961 and 1972, from 1.1% to 2.2%, but has declined slightly since; and total enrolment in colleges and universities, after more than doubling during the 1960s, is levelling off.

In short, just as the universities were reaching peak output of graduates with first and advanced degrees in science, federal support began to shrink. The chief driving force behind those trends was the spectacular expansion of the space programme and its equally spectacular decline in the late 1960s. The result, of course, was that a huge oversupply of scientists and engineers began to emerge in 1970 and 1971 and much publicity was given to unemployment of highly skilled manpower.

According to surveys conducted by the National Science Foundation (NSF), in the spring of 1971 2.6% of all scientists and engineers with first or higher degrees were unemployed and looking for work, and in June and July of that year 3.0% of all similarly trained engineers were out of work. Younger scientists and engineers were the most severely affected (unemployment rates of 5.3 and 5.5% respectively) while PhDs only experienced unemployment rates of 1.4 and 1.9%. Although unemployment among scientists and engineers was running well below the national average (in excess of 6% at that time) the plight of unemployed scientific workers received widespread attention in the press and that may have contributed to declining enrolments in the early 1970s.

Two years ago, the National Science Board, the top policy-making body for the NSF, summed up the situation thus: "Substantial changes in the demand for scientists and engineers, which may be produced by factors such as a redirection in federal funding or the state of the national economy, may occur over periods of from two to three years. But because scientists and engineers require training extending over several years, serious imbalances of supply and demand, inadequacies of training, maldistributions among areas of competence, and similar problems may be corrected only over a longer five- to ten-year span."

A number of warning signs concerning the slow-down in the growth of higher education did, however, begin to turn up unexpectedly in the late 1960s, before the unemployment situation arose. According to data discussed at a meeting last year of science manpower analysts by Alan Cartter, of the University of California, Los Angeles, the following shifts took place.

The proportion of 17- and 18-year-olds graduating from high schools peaked in 1968 and has declined since; analysts had

Fig. 1 National expenditure on research and development in the USA (1961–72). *a*, Current \$; *b*, constant 1958 \$.

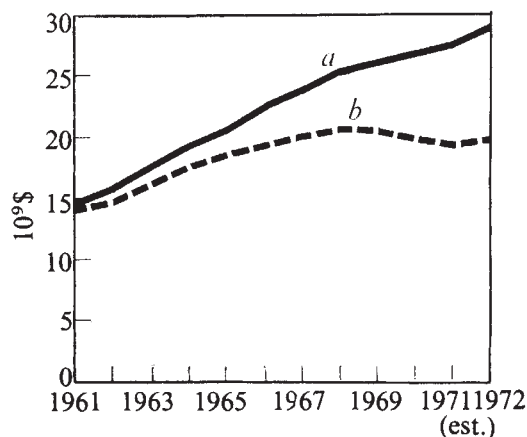


Table 1 Summary of science/engineering doctorate labour force and use (1972 and 1985)

	Total	Physical sciences	Engineering	Mathematics	Life sciences	Social sciences
1972 Estimate (thousands)						
Labour force	221	65	34	13	57	53
No. used as scientists or engineers	206	61	32	12	54	47
No. not used as scientists or engineers*	15	5	2	1	3	6
No. used as scientists or engineers as percentage of labour force	93	93	95	96	95	89
1985 Probable model (thousands)						
Labour force	375	85	63	22	92	113
No. used as scientists or engineers	293	76	45	16	85	71
No. not used as scientists or engineers*	82	9	18	6	7	42
No. used as scientists or engineers as percentage of labour force	78	89	71	73	92	63

*Includes unemployed.

predicted a yearly increase of 1% until 1980. That was followed a year later by a sudden downturn in the proportion of high school graduates entering colleges and universities—again, the proportion had been expected to increase but between 1970 and 1973 it decreased from 61.8% of all high school graduates to 57.6%. That downturn was itself followed in 1970–71 by a peak in the college graduation rate. And, as for graduate education, enrolment in graduate courses peaked in 1967–68 and has generally been dropping ever since. Moreover, the PhD completion rate peaked in 1969–70.

Those trends have not been consistent among all the sciences. Enrolments in the life sciences and social sciences have generally held up, for example, and the number of women entering and completing graduate courses has continued to increase.

The latest survey of enrolment in graduate education, conducted by the NSF, indicates, for example, that enrolment in graduate engineering courses declined slightly last autumn and enrolment in physical sciences held about steady. But the number of students entering graduate social science departments rose by about 4.4% and enrolment in graduate biological science courses shot up by 17.2%.

Nevertheless, surveying future prospects, Cartter concluded that there is likely to be a slight contraction in total enrolment in higher education at least until the mid 1990s, which will depress the academic labour market. The oversupply of doctorates in the general academic labour market looks grimmer for the period 1980 to the early 1990s than it has at any time in the past.

That prediction is supported by at least three authoritative surveys. Last year, the Office of Education came up with projections of college enrolment in 1980 which suggest that the net increase in the number of full-time faculty members in the entire decade from 1972 to 1982 will be 34,000. That is fewer than were hired in the single year 1965 and compares with an addition of 211,000 full-time faculty members between 1962 and 1972.

More recently, the Carnegie Commission for the Advancement of Teaching predicted that enrolments in higher education are likely to grow slowly, if at all, during the next 10 years, after which they will probably decline. Slow growth may, however, be resumed after about 1995.

Finally, the NSF last month issued some grim predictions concerning the manpower situation for PhD scientists and engineers in the next 15 years. Those forecasts (*Projections of Science and Engineering Doctorate Supply and Utilisation 1980 and 1985*, NSF 75–301) indicate that there is likely to be a growing imbalance between the supply of PhD scientists and engineers and the number of job openings for which their skills will be required.

Specifically, the NSF anticipates the following developments:

● Based on an analysis of trends during the past five years, there are expected to be between 375,000 and 400,000 scientists and engineers with PhD degrees available to the economy by

1985. But there are likely to be only about 295,000 available positions in activities related to science and technology.

● That projection suggests “a trend toward increasing imbalances between supply and utilisation, which would result in more non-science and engineering utilisation of science and engineering doctorates, possibly in some unemployment”.

● The NSF report notes, however, that the magnitude of unemployment is difficult to predict but it is likely to be relatively small since people with PhD training are likely to find some kind of employment, albeit outside science and technology or in occupations for which they are overqualified. In that regard, it should be noted that general levels of unemployment among scientists and engineers is now low, in spite of the fact that the United States is in the middle of a prolonged recession.

● There is likely to be a substantial shift in employment patterns, with increasing numbers of PhD scientists and engineers finding jobs outside higher education, or in jobs unrelated to science and technology. In fact, more than half of all new job openings for science and engineering PhDs are likely to be outside research and development in the next decade so that by 1985, more than a fifth of the entire doctorate science and engineering labour force will probably be employed in occupations unrelated to science and technology. Less than 10% of all PhD scientists and engineers are now so employed.

Those projections immediately raise a fundamental question about the nature of graduate education, namely, is the system which has traditionally produced people almost exclusively for academic and industrial research and development also suitable for producing PhDs for other occupations? Almost everybody who has studied the situation believes that a number of changes are required.

In addition to recommending cutbacks in enrolment, for example, the academy's astronomy committee also urged that PhD astronomy courses should be broadened so that the three-quarters of all would-be astronomers who will fail to get jobs in astronomy will be more employable elsewhere. Moreover, an *ad hoc* committee of the National Science Board recently recommended that “educational alternatives be provided to the traditional highly specialized PhD program to prepare students for a broad range of careers”.

Those overall projections mask the fact, however, that there are likely to be shortages in a few fields because of rapidly increasing federal expenditures on a number of key programmes. Just as the space programme distorted the scientific manpower situation during the 1960s, the energy research and development programme and perhaps the cancer programme are likely to distort manpower demands in the next decade.

Although it is difficult to predict exactly how many trained people will be needed to carry out those two programmes, two recent studies have raised warning signals. As far as energy research and development is concerned, the National Planning

Association (NPA)—one of the better diviners of manpower trends—has concluded that “the future supply of engineers and scientists may be inadequate to meet the demands of activities designed to increase domestic energy supplies”.

In short, the NPA reckons that the energy industry will need to recruit about 14,600 engineers and about 5,500 scientists a year by 1985. But, if recent enrolment trends in undergraduate engineering departments are maintained, the study suggests that only about 28,000 engineers will graduate from American universities in 1985. In other words, the energy industry will require more than half of all the engineering graduates, and about a third of all the graduates with degrees in the physical sciences. In 1970, by comparison, the energy industry employed only 10% of all engineers in the United States and 15% of all physical scientists. During the early 1960s, when there was high demand for scientists and engineers, many companies in the United States recruited from abroad; but the NPA study notes that supply of foreign engineers and scientists is diminishing.

There are, however, some indications that enrolment in engineering courses is beginning to pick up, perhaps in response to the possibility of a favourable job market. The Engineers Joint Council, for example, estimates that the freshman engineering class this year is 18% larger than last year's, and if that trend continues, the NPA's dire prediction that total output of engineering graduates will drop to 28,000 a year may turn out to be wide of the mark. The Engineers Joint Council also noted, however, that the declines in enrolment during the late 1960s and early 1970s resulted in a 5.5% drop in engineers graduating last year. Overall, 41,407 bachelors' degrees were awarded in engineering last year, 15,885 masters' degrees and 3,362 PhDs.

As for the cancer programme, the National Cancer Program Plan suggests that about 13,500 biomedical scientists with PhD or MD degrees will be required for cancer research in 1982. There were only about 5,500 scientists engaged in

cancer research in 1972, and the plan suggests that “a deficiency in the number of scientists may begin to occur in [fiscal year] 1975 and may continue to increase as the program expands”. It should be noted, however, that funding for cancer research is unlikely to grow as rapidly as the plan indicates and so manpower requirements will also grow rather more slowly. Moreover, enrolment in both undergraduate and graduate biology departments is continuing to increase. The NSF's projections for PhD scientists therefore indicate that there will be a close match between supply and demand for biological scientists in 1985.

In view of those predictions, it may well be asked what the federal government should do to bring supply and demand more closely into balance. First, it should be pointed out that the government's leverage on the supply side is surprisingly small. During the 1960s, for example, in spite of massive government support for science and technology, which included direct support of postgraduate students, the proportion of science and engineering graduates, as a percentage of the total numbers of graduates, remained constant (about 30% of all bachelors' degrees were awarded in science and engineering) whereas the proportion of PhD degrees in science and engineering even declined after 1962. Aside from direct support of postgraduates in energy-related fields, the federal government has recently phased out most of its direct support programmes for science and engineering students (much against the wishes of the universities, which have lost a useful source of income).

The demand side is likely to be influenced chiefly by enrolment patterns in higher education and by total government support for science and technology. As noted above, however, there is likely to be little growth in the college-age population and, therefore, in higher education. As for total government support of science and technology, if recent trends are anything to go by, a period of slow growth is likely to be in store for most areas of science, which at least will be an improvement on the stop-start trends of the late 1960s and early 1970s.

Indian scientific and technical personnel abroad

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Although India educates large numbers of scientists and technologists, there is a considerable brain drain as a result of lack of opportunities for employment. To make full use of their trained manpower, the Indian government has started some schemes to help scientists who wish to return home.

MANPOWER being an essential input for any developmental programme, India adopted in the post-independence years a programme of rapid expansion of education in science and technology to meet the requirements for development of science and technology. The number of universities was gradually increased. Capacities for postgraduate education in the basic sciences were extended and the scope of technical education was broadened through the updating and expansion of the existing institutions and establishment of new ones. A number of Regional Engineering Colleges and a chain of five Indian Institutes of Technology (IIT) came into being and the output grew rapidly each year. Table 1 illustrates the growth of universities and other institutions of higher learning and Table 2 the output, at different academic levels, of scientists, engineers and medical

personnel. Although there were only 20 universities in India in 1947 the number had risen to 86 by 1972. Higher education and research in professional subjects such as agriculture and engineering attracted particular attention and some newly established universities were exclusively

Table 1 Growth of educational institutions in India

	No. of universities, IITs and other institutions deemed as universities			No. of institutions offering postgraduate courses in engineering	No. of medical colleges
	Universities	IITs	Other		
1945	17	—	—	5	15
1947	20	—	—	5	22
1950	27	—	—	6	29
1952	30	1	—	10	30
1954	31	1	—	14	35
1956	35	1	—	21	46
1958	40	2	2	26	51
1960	45	4	2	30	62
1962	55	5	4	33	71
1964	62	5	8	43	81
1966	68	5	8	56	90
1968	76	5	9	62	92
1970	83	5	9	67	95
1972	86	5	9	77	99
1974	86	5	9	80	105

Table 2 Output of scientific and technical personnel

	BSc	BSc Ag	MSc	MSc Ag	PhD Science	PhD Ag	MBBS	MD/MS	BE/BSc Eng. & Tech	ME/ MTech Eng./Tech	PhD Eng.
1945	4,406	403	745	39	NA	NA	609	NA	987	23	NA
1947	5,996	535	905	79	NA	NA	959	NA	1,076	30	NA
1950	9,628	1,000	1,425	154	NA	NA	1,557	88	2,065	100	NA
1952	11,087	870	2,129	223	108	5	2,164	113	2,882	118	12
1954	14,427	910	2,911	208	164	4	2,582	110	3,104	147	19
1956	16,126	886	3,255	214	210	11	2,732	171	4,163	278	23
1958	18,920	994	3,841	313	216	8	2,839	281	4,237	378	20
1960	22,693	1,700	5,382	488	361	11	3,387	397	5,660	606	18
1962	26,930	2,612	7,218	704	435	50	3,945	525	8,216	756	20
1964	34,046	4,099	8,882	823	537	19	4,452	771	9,387	665	26
1966	42,437	5,259	10,008	1,191	774	94	6,558	1,049	13,015	980	39
1968	59,606	6,239	12,682	1,372	1,100	120	8,916	1,254	15,771	1,076*	66
1970	83,610	5,909	16,578	1,670	1,212	217	9,562	1,266	17,748	1,231*	98
1972	NA	NA	NA	1,945	1,310	309	10,315	NA	16,487	1,408*	76
1974	NA	NA	NA	2,267	NA	NA	11,024	NA	14,704	1,610*	NA

*Estimated. NA, not available.

for this purpose. The IITs were established as centres of excellence for education and research in engineering and technology. In the field of medical education, the number of colleges offering degree-level education rose from 15 in 1947 to 105 in 1974 and a few institutions were established exclusively for postgraduate education and research in medical sciences. A significant feature of this period is a proportionately large increase in the output of postgraduates in agriculture, engineering and medicine. The stock of scientific and technical personnel increased rapidly, as Table 3 shows. If the trends continue the estimated stock by the end of 1975 would be about 624,000 graduates in science, 229,000 postgraduates in science, 278,000 graduate engineers, 391,000 diploma engineers and about 117,000 medical doctors.

But despite the expansion of facilities for higher education and research, a number of Indian scientific and technical personnel have continued to go abroad over the years. Education and training overseas is a century-old tradition with India's scientific and technical personnel; many qualified people go abroad for further studies, or training, or to acquire wider professional experience. Overseas exposure, especially in a developed country, helps expansion of one's

couple of years, some stay longer and others settle permanently in a foreign country. Over the past two and a half decades relatively larger numbers have been staying away for longer periods.

India's scientific and technical personnel abroad have been a matter of concern for some time and have generally found a prominent place in any discussion of the 'brain drain' from developing to developed countries. It is worth considering if all these scientists can be grouped under 'drained brains'. The Colombo Plan Consultative Committee, in its 22nd meeting in New Delhi in October and November, 1972 suggested "the external migration of personnel at the skilled, technical and professional levels for employment abroad under circumstances in which they could otherwise have been employed at once or in the near future, productively at their proper attained level of professional skill in their own country at work of national importance" as a definition of brain drain. From this definition, one might perhaps conclude that the number of Indians abroad constituting a brain drain is small. People planning to come home in the foreseeable future cannot be considered; it is those who have settled abroad more or less permanently and those who have not yet decided their

Table 3 Stock of scientific and technical personnel

	1950	1955	1960	1965	1970
Scientists (graduates)	66,900	114,000	185,000	300,900	480,200
Scientists (postgraduates)	1,000	30,000	51,400	93,400	152,700
Engineers and technologists (graduates)	21,600	37,500	62,200	106,700	185,400
Engineers and technologists (diploma level)	31,500	46,800	75,000	138,900	244,400
Medical personnel (graduates)	18,500	29,000	41,600	60,600	97,800
Medical licentiates	33,000	35,000	34,000	31,000	27,000
Total	188,000	292,700	450,000	731,500	1,187,500

academic, industrial, professional and social experience, and mature students can get particular benefit from it. The post-war period apparently opened up newer and greater opportunities abroad, and as a consequence the number of Indian scientists going abroad during the past 25 years has grown considerably. A good number are going for a first degree, with plans to work for subsequent higher degrees. Opportunities for employment in India have not developed along with the development of educational facilities and this has led a section of the educated unemployed to look for posts outside India. Most return home after a

time of return who constitute a potential brain drain.

It is difficult to obtain a precise estimate of the amount of India's scientific and technical manpower that is abroad and even more so to collect details of their activities. A special section—the Indians Abroad Section—of the National Register of Scientific and Technical Personnel of India was started in 1958 to gather this information. Indian scientists, engineers, technologists and medical personnel abroad for study, further training or employment are encouraged to enrol in this section of the register. Although registration is voluntary, about 20,000 have enrolled so

far (Table 4). About 50% of the registrants have since returned to India, which would leave about 10,000 still abroad. But this figure is believed to be far short of the actual number. On other available data it was estimated in early 1971 that 30,000 qualified Indians were abroad, of which 15,000 were engineers, 9,000 medical doctors and 6,000 scientists.

An analysis of the data in the Indians Abroad Register may be of some interest. About 90% of the 19,824 registrants are from four countries, the USA, the UK, Germany and Canada—the USA accounting for about 38% and the UK about 35%. Among those registered from the USA, scientists constitute the highest proportion (46%) followed by engineers (37%) and medical personnel (12%). Medical personnel and engineers form the highest proportion (39% each) among those registered from the UK, scientists make up 16%. Of the registrants from Germany, engineers are the largest group (63%) followed by scientists (22%); medical personnel constitute only 3%. Fifty per cent of the registrants from Canada are scientists and 33% engineers.

More than 50% of the scientists in the register enrolled from the USA, about 16% from the UK and about 10% from Canada. Among the engineers about 33% are from each of the USA and the UK and about 16% from Germany. About 70% of medical personnel are from the UK and a little over 20% from the US.

in the public sector, acts as constraint on quick absorption in regular employment. It was, therefore, necessary to evolve a scheme which would ensure temporary placement, at least for those better qualified, on their return from abroad. The Indian government, therefore, instituted in 1959 the 'Scientists Pool' for the temporary employment of well qualified Indian scientists, engineers, technologists and medical personnel, particularly those returning from abroad without a job. Later, social scientists were also brought within the purview of the pool scheme. Persons with high qualifications, who have not been abroad are also considered for the pool—an unorthodox system of temporarily employing and making use of highly qualified people while they look for regular employment through the usual channels. Selections for the pool take place on a continuous basis throughout the year. Everybody enrolled in the Indians Abroad Register is automatically considered for selection near the time of their return, provided they do not have a job in India. The Scientists Pool is operated by the Council of Scientific and Industrial Research at New Delhi.

Those selected are attached to appropriate organisations and receive a salary (actually more of a stipend) from the Council of Scientific and Industrial Research. Any scientist in the pool is free to try for any job in India and leaves the pool on securing one. Pool appointments are for a period of one or two years. If a pool scientist is not able to find a

Table 4 Progressive rise in the registration in the Indians Abroad Register

	Science	Engineering	Technology	Medicine	Social science	Management and/or accountancy	Total
1959	678	1,083	145	187	—	215	2,308
1960	975	1,685	280	295	—	270	3,505
1961	1,271	2,287	418	403	—	331	4,710
1962	1,586	2,735	510	583	—	375	5,789
1963	2,070	3,310	636	850	—	432	7,292
1964	2,495	3,945	707	1,175	—	471	8,793
1965	3,006	4,535	800	1,575	13	530	10,459
1966	3,413	5,000	892	1,910	76	552	11,843
1967	3,754	5,279	946	2,135	125	568	12,807
1968	4,048	5,513	988	2,384	154	574	13,661
1969	4,420	5,760	1,020	2,670	188	579	14,637
1970	4,790	6,015	1,050	2,945	239	594	15,633
1971	5,161	6,259	1,083	3,218	266	603	16,590
1972	5,497	6,567	1,107	3,385	305	606	17,467
1973	5,833	6,977	1,136	3,582	338	612	18,478
1974	6,131	7,274	1,171	3,726	351	617	19,270
1975	6,330	7,455	1,188	3,855	374	622	19,824

Table 4 also reveals that the number of Indian scientists enrolling in the Indians Abroad Register is progressively diminishing. Whether this is because of a gradual decrease in opportunities abroad in recent years can only be guessed.

The other interesting fact is that almost all the registrants state their intention of returning to India sooner or later. This obviously brings out the weak side of the register. People who have more or less settled abroad or persons who are undecided about their return do not bother to enrol. Most registrants are on academic assignments but the numbers employed in industry, particularly in production, and those holding senior positions in academic fields are low. A special effort to collect information about such personnel has been initiated recently by the Indian Missions in some developed countries.

India's scientific and technical personnel abroad, properly harnessed, can contribute a great deal. It is, therefore, a question of what can be done to facilitate their return and to use them effectively once they have come back. The usual procedure of recruitment in India, especially to jobs

regular job within this period, his case is reviewed and the appointment may be extended.

Table 5 gives a breakdown of the number of people in the pool. Up to the end of February 1975, some 10,753 persons had been selected, of whom 9,889 were from the Indians Abroad Register. Of these, 6,163 returned to India and 3,635 of them secured regular employment in India after working for some time as a pool scientist; another 1,070 were able to find a regular job without help from the pool. About 900 other people are believed to have settled in India in regular employment as they did not respond to pool enquiries.

The pool scheme does, however, have its inherent limitations. As pool scientists are only temporary, the user organisations are unable to give them long term assignments. Nevertheless, many pool scientists produce good work and many organisations are keen to obtain scientists, engineers and doctors through the pool system.

An opinion survey of ex-pool scientists, carried out by the CSIR in 1969–70, found that most of them were fully

satisfied and nearly all were happy with at least some part of the scheme. There was some dissatisfaction arising from temperamental differences, high expectation, and conflict of interest between the internal staff and the pool scientist. Nevertheless, 46% of the respondents stated that the pool placement gave them confidence to return, 53% felt that it gave a ready working opportunity and 67% appreciated the financial benefit so necessary at the beginning. The pool scheme can, therefore, be considered to have been of considerable help to Indian scientific and technical personnel returning from abroad.

The Indian government also approved a scheme of supernumerary appointments for the quick absorption of outstanding scientists whose services might be useful for research and development projects. The posts are to be specially created for them and salaries appropriate to their background can be offered. The scheme has, however, been used only cautiously so far.

to obtain infrastructure facilities such as land, water and power supplies. The Council of Scientific and Industrial Research is the executive agency of the scheme, but its recent introduction means that its impact is yet to be felt.

Most of the schemes discussed above have their limitations. Proper and full use of India's vast scientific and technical manpower resources is linked with employment opportunities and appropriate working facilities. The economic growth of a country provides professional opportunities within that country for the scientific and technical personnel. The trained personnel are used in industry, agriculture, research and development and public health to the extent that the economy can absorb. As the growth of the economy in India has not been as expected, this has created the problem of making proper use of India's scientific and technical personnel at home and abroad. Considerable thinking is going on to create effective demand for scientific and technical manpower in viable areas. Emphasis is being placed

Table 5 Scientists pool

	Science	Engineering	Technology	Medicine	Social science	Total
1959	77	69	26	25	—	197
1960	50	60	15	38	—	163
1961	240	160	26	98	3	527
1962	120	79	28	159	7	393
1963	185	365	37	247	5	839
1964	265	485	37	345	7	1,139
1965	324	321	49	266	8	968
1966	205	162	33	219	10	629
1967	187	156	24	220	20	607
1968	263	113	20	191	12	599
1969	321	167	18	219	18	743
1970	280	151	15	227	9	682
1971	364	215	18	160	14	771
1972	356	369	21	164	27	937
1973	249	245	16	138	10	658
1974	363	253	24	178	19	837
Total	3,849	3,370	407	2,894	169	10,689

Although the schemes of the scientists' pool and supernumerary appointment help those who return to India, they have not proved sufficiently attractive to those undecided about their return or those who have settled abroad. Even though it is not possible to bring back every Indian abroad, some attempt to make use of their talent for specific purposes is worthwhile. Some may visit India for a short time in a professional capacity. Their association with research and development organisations or academic institutions in India may be of mutual interest. Schemes of short term appointment as research associates or visiting scientists have recently been introduced by the Council of Scientific and Industrial Research. People visiting India for a short time can be offered such appointments in national laboratories in cases where their background fits the requirements of the organisations. In the academic field, the universities in India are now in a position to offer short term appointments to Indian scholars abroad during their sabbatical leave. Apart from the immediate gain, such associations provide people with the opportunity to become acquainted with conditions in India and may induce them to stay permanently. The Indian government has also recently approved a 'package scheme' to enable Indian scientists and technologists engaged in production or management in industrial organisations abroad to set up manufacturing units in India. They will be helped to secure industrial licences, capital goods clearance and import licences, and if necessary entrepreneurial loans from public financing bodies in India, and

on schemes which provide greater employment and also on efforts to create employment opportunities in different sectors. It is not necessarily the targets and investment in an economic Plan, but the working strategy, that decides employment potential within the constraints of the given resources. It also calls for a close look at the technology to be used for various developmental projects.

Much employment is likely to be generated for various categories of personnel during India's Fifth Five-year Plan. Employment opportunities for scientific and technical personnel are, however, closely linked with the Science and Technology Plan, an integral part of the Five-year Plan. This is the first time in India that a separate body—the National Committee on Science and Technology—has been set up with the task of formulating a national plan for science and technology. This plan is one of the major policy instruments for achieving self-reliance. It has been prepared with a view to solving pressing problems of agricultural growth, industrialisation, productivity, environmental deterioration and population growth, and gives highest priority to the application of the scientific and technical skill already built up and the development of indigenous technology. The research and development efforts envisaged are expected to open up vast employment opportunities for scientific and technical personnel. It is estimated that about 120,000 jobs will be generated during the implementation of the Science and Technology Plan, of which approximately 10,000 will be for personnel with high qualifications.

Peculiar problems of the British Civil Service

David Davies

Employer of 17,000 scientists, the British Civil Service faces special problems in the motivation and use of its more senior members. Maybe this calls for some fairly radical solutions.

IN 1854 two major reports were published on the concept of the Civil Service: Macaulay on the Indian Civil Service and Northcote and Trevelyan on the British Civil Service. In many ways British experience in India influenced the development of the Home Civil Service, and in both services the problems of the early 19th century had been those of nepotism and incompetence. There was talk, in the Northcote-Trevelyan report, of admission to the Civil Service (and this meant the administrative sector) being sought after by the 'unambitious, indolent and incapable'; (see box). The report went on to hint that the lightness of work and security of employment made the Civil Service a natural home for "sickly youths".

The solution to all this according to both Northcote-Trevelyan and Macaulay was to subject applicants to competitive entrance examination. Macaulay spelt out his examination proposals in detail:

English language and literature:	
Composition	500
History	500
General literature	500
	Total 1,500
Greek	750
Latin	750
French	375
German	375
Italian	375
Mathematics, pure and mixed	1,000
Natural sciences	500
Moral sciences	500
Sanscrit	375
Arabic	375
	Total 6,875

"It seems to us probable", he goes on reassuringly "that of the 6,875 marks no-one will ever obtain half". The marking system was simply to ensure equal access to the classical scholar, mathematician and such as the young man proficient in "English, French, Italian, German, geology and chemistry".

The Fulton Committee of 1968, the most recent major investigator of the Home Civil Service observed that the service was still fundamentally the product of the nineteenth century philosophy of Northcote-Trevelyan. From the 1854 reports "emerged the tradition of the 'all-rounder' as he has been called by his champions, or 'amateur' as he has been called by his critics".

In 1854 the government employed practically no scientists and there was no such thing as a national laboratory. And yet the story has its modern aspects. For one thing, the consequent evolution of the generalist administrator as the top dog of the Civil Service rankles with some specialist civil servants (scientists, engineers and so on) whose access to higher management and policy making was (at least when Fulton reported) restricted. For another, the sort of noises that were being made in 1854 about a quiet secluded profession leading to narrow views have been made ever since about civil servants, and as scientists have become civil servants they too have reaped some of this criticism. For instance, in 1931 the Carpenter Report on the

Those who enter it generally do so at an early age, when there has been no opportunity of trying their fitness for business, or forming a trustworthy estimate of their characters and abilities. This to a great extent is the case in other professions also, but those professions supply a corrective which is wanting in the Civil Service, for as a man's success in them depends upon his obtaining and retaining the confidence of the public, and as he is exposed to a sharp competition on the part of his contemporaries, those only can maintain a fair position who possess the requisite amount of ability and industry for the proper discharge of their duties. The able and energetic rise to the top; the dull and inefficient remain at the bottom. In the public establishments, on the contrary, the general rule is that all rise together. After a young man has been once appointed, the public have him for life; and if he is idle or inefficient, provided he does not grossly misconduct himself, we must either submit to have a portion of the public business inefficiently and discredibly performed, or must place the incompetent person on the retired list, with a pension for the rest of his life. The feeling of security which this state of things necessarily engenders tends to encourage indolence, and thereby to depress the character of the Service. Again, those who are admitted into it at an early age are thereby relieved from the necessity of those struggles which for the most part fall to the lot of such as enter upon the open professions; their course is one of quiet, and generally of secluded, performance of routine duties, and they consequently have but limited opportunities of acquiring that varied experience of life which is so important to the development of character.

From the Northcote-Trevelyan Report, 1854.

Government Scientific Establishments tried to encourage scientists to interchange between research establishments and universities by sharing a common (university-based) pension scheme. (This has now been abandoned.) In 1941, A. V. Hill wrote¹: "In many of the Departments of government, notably those of the Defence Services, . . . the danger of stagnation and complacency exists". In the 1960's committees chaired by Mott, Sutherland and Zuckerman all in different ways addressed the problem of stagnation within civil service science. In 1972, an OECD report² noted that "job security may very well transform agencies in the government sector into havens for second rate scientists who can be assured of making a career there". *Plus ça change*.

Who they are, what they do

The British Civil Service employs roughly 700,000 people; about 17,000 of these are in the Science Group and are employed (at least in theory) to practise science. It is difficult to know how many scientists there are in the country at large, but figures for the first destination of university graduates suggest that about one in ten of all recipients of higher degrees in science go into the Civil Service, and one in fifteen of all graduates do likewise.

The scope of the operations of the Scientific Civil Service is

Table 1 Numbers and changes in 1973

	Post (recruitment qualification)	No. (women in brackets)		Salary (provisional, revised April 1975)	Promoted to	Recruited to
Open structure	Under Secretary and above	Includes 85 scientists			11	No data
Other scientific grades	Chief Scientific Officer	32	(0)	£10,950	4	0
	Deputy CSO	200	(0)	*	17	0
	Senior Principal SO	618	(5)	£8,650-£9,798	50	3
Science Group	Principal SO	2,011	(43)	£5,514-£7,205	152	10
	Senior SO (degree and high quality experience)	3,516	(146)	£4,185-£5,778	171	43
	Higher SO (degree and experience)	3,549	(266)	£3,254-£4,454	360	79
	SO (degree)	2,946	(470)	£2,149-£3,565	130	151
	Assistant SO (school examinations)	4,065	(1,220)	£1,276-£2,560	—	563

Source: *Civil Service Statistics* 1973 (HMSO, London).

*Not yet made public.

also wider than that in most other countries, where governmental science requirements are more often contracted out.* There are more than 100 departmental research establishments covering fields as diverse as road research, maintenance of physical standards, forensic science, meteorology, nuclear weapons and the control of plant disease. Sixty per cent of all scientific civil servants work for the Ministry of Defence. For the rest, there is a roughly equal division among Trade and Industry, Agriculture, Agriculture (Scotland) and Environment. Other departments employ smaller numbers of scientists.

An extensive history of civil service science is not called for here, but some landmarks should be noted. Research efforts by and for government (apart from the Greenwich Observatory founded in 1675) could be said to have started with the Geological Survey, founded in 1835 and the National Physical Laboratory, created in 1899. In the twentieth century the Department of Scientific and Industrial Research (set up in 1915) established various further national research laboratories, all of which were advised by boards of independent scientists, industrialists and, later, trade unionists. At the same time defence research stations were also, of course, being established.

During the Second World War there was an enormous growth in the amount of government science done, almost all, obviously, directed to the war effort, and the increasing significance of science to national needs led to the setting up in 1946 of a formalised Scientific Civil Service. Until 1971 the service comprised three classes—Scientific Officer, Experimental Officer and Scientific Assistant, each with its own grading system, but one of the consequences of the Fulton Report on the Civil Service (1968) was a reduction in the number of classes. The formation of the Science Group represented, as Fulton foresaw “abolition of the divisions between higher and lower classes, and a continuous grading system from bottom to top in each occupational group”.

Fulton also observed that scientists are ‘frequently given neither the full responsibilities and opportunities nor the corresponding authority they ought to have’. It recommended ‘more training in management and opportunities for greater responsibility and wider careers’. To an extent this has been done at the very top of the Civil Service where an ‘open structure’ now exists. Those who reach Under Secretary level (see Table 1) are not separated by specialism; about 10% of these 800 top people are scientists. This is not to say that people at the top can do just anything. Many jobs in the open structure are obviously highly specialised (the three directors at the Meteorological Office are Under Secretaries or above). Nevertheless when a scientist has reached the open structure level it is at least in theory possible for him to move to more general policy-making posts either within or outside science.

The typical British civil servant scientist, however, will not make the top eighty. He or she will have entered with a science degree at the age of 22. He or she will be promoted to Higher Scientific Officer in the late 20s, to Senior Scientific Officer a few years later and to Principal Scientific Officer in the late 30s. The next step may not come at all for the ‘typical’ person; but in the 40s he (practically no she now) could take on more administrative responsibility as a Senior Principal Scientific Officer.

He or she will probably work for the Ministry of Defence in a delightful rural setting and never give a moment’s thought to the possibility of working elsewhere, either within or outside the service. The chance of his or her getting the sack or being declared redundant is negligible. The facilities are excellent and there is great satisfaction to be derived from the work, which is unlikely to make many demands outside normal working hours. There are few, if any, pressures to submit one’s work to any form of external evaluation (particularly if in the classified sphere). Pay is excellent and the government has recently shown itself willing to bend the social contract in giving pay rises. A good pension scheme awaits. Perks on the other hand are poor unless you value a ticket to the Air Show at Farnborough, or being in the ballot for tickets to see the Trooping of the Colour . . .

Behind the word ‘typical’ lies a sizeable variation in abilities, particularly after Fulton, when the scientific classes were unified. On the one hand there are the former Experimental Officers and Scientific Assistants, who will enter as Assistant Scientific Officers straight from school, and might reasonably hope to rise to Senior Scientific Officers eventually. On the other hand are those who enter only after obtaining ‘high quality experience’ and who would start as Senior Scientific Officers, with a reasonable hope of making it to SPSO.

Promotion is by appearance before a Board. In the Science Group there is a measure of so-called flexible complementing—an establishment is not defined in terms of the numbers it may employ in each grade but individuals may rise naturally to their most appropriate level. This lack of the ‘dead men’s shoes’

*Comparisons are complex, however. In any country in which a substantial amount of research and development is done the evolution of government-supported laboratories has followed different pathways. In the UK, the Haldane doctrine (1918) separated off fundamental research from ministerial departments and at present there are large numbers of scientists employed by the research councils on projects inappropriate to individual universities yet without a natural home in a ministry, such as oceanography and experimental high energy physics. There are many others in laboratories supported by the Medical Research Council and based on universities, and there are yet more in the UKAEA. These are sometimes known as public servants as opposed to civil servants; their modes of recruitment terms of service and so on are very similar. Although statistics quoted here do not include public servants, most of the general remarks made are equally applicable to them. In other countries things have evolved differently, particularly where there are federal and state governments. Federally Funded Research and Development Centers in the United States, Max-Planck-Gesellschaft in Germany and the Institut National de la Santé et de la Recherche Médicale in France all sit differently on the fringe of in-house government-sponsored research.

approach to promotion is widely appreciated although one does still sense an obsession with grades in the Scientific Civil Service.

Demands on them

The lot of the civil servant scientist seems at first sight to be a much happier one than that of his colleague in industry or a university. Shielded from the short-term pressure to be productive and from the constant questioning and irreverence of the young, the civil servant can pursue a linear career in which he gains seniority as he gains experience. But does the immense stability of Civil Service science act as a positive hindrance to using scientists' skills in the most effective way? Many would argue that the duties of the civil servant scientist are so different from those of other scientists that it is foolish to apply similar sorts of yardstick—except in salary, of course. There is a lot in this—much of the scientific work is routine, and a large proportion of employees are engaged in routine laboratory and field work and neither have the qualifications for more, nor would seek broader horizons. But the sort of work called for in the name of research is likely to be every bit as demanding as industrial or university research, and the problems to be solved generally much greater, either because they are complex and involve lots of people or because there is some element of a race, military or civil.

The growth of the service since 1931, when it was estimated that there were 1,053 scientific and technical professional people in government employment, has been phenomenal, but figures of Jones³ show rather clearly that the growth was largely over by 1951. Apart from additions to strength from transfers of United Kingdom Atomic Energy Authority (UKAEA) employees into the service there has been no significant change in the size of the service since 1961.

Table 2 Scientific Civil Service, 1973

Age	No.	Entrants	Leavers
Under 20	654	299	88
20–24	2,280	315	249
25–29	2,358	156	166
30–34	2,054	34	52
35–39	1,801	18	22
40–44	1,958	5	15
45–49	2,301	22	13
50–54	1,706		13
55–59	1,268		21
60 and over	557		188
	16,937	849	827

Source: *Civil Service Statistics, 1973* (HMSO, London).

This is quite a surprise. During this period we have seen immense university expansion, an Election (1964) based on harvesting the white heat of the technological revolution, a growing concern with environmental matters (calling for more governmental intervention), a decline in the popularity of science among students and a major economic crisis resulting in a great reduction in the recruiting of university staff. Through it all the scientific civil service has remained stable in size. One of the consequences of this is a remarkably uniform age distribution of civil servant scientists (Table 2).

Flux—or lack of it

This table also clearly shows some striking facts about the immobility of the profession. An utterly trivial percentage of employees over the age of 30, (by which time some of the junior entrants performing routine tasks will have left), leave before

retirement for any reason at all—and practically no new people are hired.

There are routes in for the over-30s. There are a few short-term appointments usually for specific duties. In addition if a senior job falls vacant and there is no appropriate replacement in the establishment, the department may be 'trawled'. If the department produces nothing, the whole Civil Service may be 'trawled'. If again nothing comes forward, recruitment can be from outside by competition. As one research director put it, 'by the time we can advertise on the open market, we've forgotten what we wanted him for'.

There are routes out, too. It is in theory possible to dispense with the services of a scientist who is not contributing, but the procedure is lengthy, and if the scientist will not take the hint and go (and with an excellent pension scheme, why should he?) it is often easier to let things slide than provoke a bloody battle. Whatever management skills senior civil servant scientists may possess, one of them is clearly learning how to make do with the people you have.

If the service does not change in size, how does it manage to adapt to change, and particularly growth, in mission? To a certain extent one suspects that scientists are being called on to work harder than they were ten years ago, say. This of course, is an extremely subjective opinion—everyone always says they are swept off their feet and things never used to be like this. But also to a certain extent the government has to rely on the ability of older scientists to make the necessary adjustments and learn the skills of the 1970s. This is asking a lot: from Table 2 it is clear that nearly half the staff must have joined the service before the transistor and the digital computer were commonplaces. Industry recognises the ageing problem by moving most of its research and development staff on by the age of 35 (this is accepted both by the employer's and employee's side of the civil service⁴). Academic life recognises it by the reverence it attaches to the graduate student and post-doctoral worker. The Civil Service is in a more difficult position because it can do so little about its more senior members and has no real mechanism by which its more junior members have to face the fact that they are not cut out for research and development after, say, a trial period of five years. True there are annual reviews such as every good employer carries out, but although there are some attractive carrots the stick of intellectual ridicule or dismissal is lacking.

Remedies

The Civil Service Department (representing the government) and the Institution of Professional Civil Servants (IPCS) (representing the scientists) do not seem unduly worried by the uniform age distribution. Both point to the different sorts of contribution that can be made by more senior men. The concern is much more obvious among the middle managers—directors of laboratories and leaders of teams. 'My biggest problem?', said one such, having vouchsafed a ten-second interview *en passant* on the stairs, 'Getting rid of all my unproductive PSOs'. Others spelt out in a more leisurely way their worries. There just are not enough administrative-type posts to go around in the laboratories; they would like to see the concept of the golden handshake seriously discussed as a humane and effective way of facing up to the problems of the senior scientist. It is by no means clear that such a radical solution would be resisted by the scientists themselves, many of whom are only too aware that they are marking time but who can find no escape mechanism. With a recent liberalisation of the transferability of pensions, things should be somewhat easier.

There are also other possibilities worth exploring. For years people have talked of increasing the mobility of scientific civil servants, but in general nothing has happened. There is, of course, no such thing as an automatic sabbatical (although intelligent individuals have been able to persuade the manage-

ment that the future of the Civil Service depended on their secondment for a year to establishments in Australia, California or the South of France). And resistance to even the idea of mobility with a return ticket, such as the Bondi report⁵ advocated and attempted to stimulate, is surprisingly strong. The IPCS told me that on the whole they opposed the Bondi conclusions partly out of scepticism that mobility served any generally useful purpose and partly out of concern that exchange schemes put members at a disadvantage by perturbing the normal channels of promotion. For much the same latter reason they were not attracted to the idea of more people coming late into the service. It must be remembered that the IPCS has a fairly wide constituency and although some of the advantages of mobility may seem self-evident to those who have already profited from it, it can be quite clearly seen by others as a threat to the orderly career structure that they had always been led to expect.

On the other hand, the IPCS plans to make an increasing amount of noise in the near future on career prospects for its more senior members. The opportunities for scientists, it asserts, 'do not come within a thousand miles' of those open to administrators. As a start it plans a campaign to get the open structure concept moved further down the service to the Principal level, so the PSOs and above would be indistinguishable, at least in name, from their administrative counterparts. I remain to be convinced, on the basis of the scientists that I met, that there was as much jealousy of the administrators as the IPCS would make out. Scientists on the whole do not join the Civil Service having in mind the administrative prospects it may hold out in later years, and their loyalty tends to remain with science even when the relevance of their skills may wane. Besides, the environment and nature of the work is usually pleasant. Further, the attractions of the flexible complementing system in science are considerable. Nonetheless, although the IPCS may be overstating what its members actually want, it could be fairly near the mark on what they ought to want—a chance to look carefully in their forties (or before) at prospects outside science and yet within government service, for not all would willingly accept a golden handshake.

The dilemma is this: it is no good wanting to keep mobility, late entry and so on away from the Science Group but expecting other parts of the Civil Service to welcome scientists with open arms. For one thing without a loosening up of the rigidity of the structure, scientists cannot be expected to acquire the horizons that will make them seek and welcome new prospects. For another, administrators will say 'you wouldn't loosen up your structure—we are professionals too, why should we loosen up ours?'

Speeding the route to the top

Not all the manpower problems of the Scientific Civil Service are those of motivating the middle-aged. A more pleasant problem is that of spotting the real high flier among the hundreds of scientists who may be in any establishment—and doing it early enough that he or she gets the chance to be effective young. Whenever general comparisons are made between civil services (as for instance Fulton did between British, Swedish, United States and French) unfavourable remarks are made about the age at which people reach the top levels in Britain. In the United States the comparison cannot be a strict one since there is so much greater scope for the 'in-and-outer' scooped up from industry or academic life, given a run of a few years of running something big and then allowed—even encouraged—to move on. But elsewhere it is clear that the remarks are often justified—in the administrative sector in Britain there is often too much of an orderly progression. The Science Group has quite a good record of giving early and major responsibility to people of promise, and directors of major establishments are often appointed well before the age of fifty.

Promotion for the highly talented does not necessarily mean an increase in the administrative burden. Although SPSOs and above normally have rather clearly defined administrative responsibilities, individuals can be promoted to these levels on the basis of their scientific merit alone. It is thus possible to reward the intellectual high flier without asking him to run the show, and about a fifth of promotions at this level are on this basis. Even so there is much agonising over how to move people up quickly, particularly now that a unified class structure means that there is great diversity in those coming up for promotion each year.

Conclusion

The scientific civil service is neither growing nor shrinking at the moment; its stability over the past twenty-five years is probably a combination of the great job security in the Civil Service and a genuine desire not to expand organisations which are difficult to contract at a later date. The perennial complaint against the civil servant is that he is immobile and, lacking anywhere else to go, populates the research laboratory for too long. But what humane solutions are there to this? Maybe the golden handshake. Maybe more middle-level administrative and executive opportunities outside science. For sure these matters cannot be neglected for much longer.

¹ Hill, A. V., *The Ethical Dilemma of Science*, 49 (Rockefeller Institute Press, New York (1960)).

² *The Research System*, 1 (OECD, Paris, 1972).

³ Jones, R. V., *Proc. R. Soc.*, A342, 481–490 (1975).

⁴ Pay Board, *Civil Service Science Group, Appendix B* (HMSO, London, 1973).

⁵ *Interchange of Scientists* (Chairman Bondi, H.), (HMSO, London, 1974).

Scientific manpower forecasting as an aid to planning in Europe

R. E. Woodham

Manpower forecasting as a basis for educational or economic planning in the long term is fraught with problems, but a more important problem on a short time scale is the annual variation in the employment of new graduates by industry, particularly in the UK. Smoothing this out would probably lead to more consistency in the flow of students from schools to science departments in universities.

Most countries, developed and less developed alike, have experimented with manpower forecasting in one form or

another, and their motives for doing so are varied. Broadly speaking, however, the basic reasons for making such predictions are to improve educational planning, to assist in economic planning in the sense of working out the manpower required to produce a certain increase in the gross national product, and to help in vocational planning—by providing the raw material for individual decisions on careers, for example.

Obviously no two countries have quite the same mix of motives for doing manpower forecasting, so the techniques differ, which makes international comparisons difficult. Also, depending on the objective, the forecasting exercise may entail

looking at manpower requirements by industries, industrial sectors or fairly small occupational groups such as 'scientists', 'engineers' or 'the highly qualified'. Looking even more closely, one finds that in posing manpower questions words have to be interpreted most carefully: 'requirements' and 'needs', for example, have different connotations—the former implying the manpower required to achieve a target and the latter introducing more of a social element and implying as much a political pronouncement as a forecast—for example, that higher education should be available to everybody rather than on a selective basis.

Planning UK scientific manpower

The acid test of manpower forecasting is its accuracy, yet sometimes that is not easy to gauge because the criteria may themselves be completely determined by the forecasting technique. If you design a questionnaire to find out industry's manpower 'requirements' for example, you get an answer that is uniquely related to the way in which the questions were worded. This can be illustrated by the various forecasting exercises done in the UK for scientists and engineers since

Table 1 Percentage changes in earnings, for the periods specified, revealed by surveys made by professional institutes in the UK

		26-30	Age 36-40	46-50	All workers*
Chemists	1956-59	17.6	18.7	21.2	13.8
	1959-62	16.8	19.4	19.5	17.0
	1962-65	18.4	16.8	17.2	23.5
	1965-68	12.2	9.1	11.4	17.4
	1968-71	25.3	22.7	25.3	33.5
Engineers	1966-68	11.5	11.1	11.9	11.0
	1968-71	25.7	23.5	20.5	33.5
Biologists	1968-71	21.1	23.3	21.2	33.5

* Professional and non-professional.

the late 1950s. In *The Practice of Manpower Forecasting*¹ (page 240) Gannicott and Blaug examine the many government reports on scientific manpower which emerged in the 1960s and conclude that, on the whole, they placed far too much credibility on their own forecasts. When actual employment fell short of the 'aspirations' of employers, as revealed in questionnaires (they say) the cause was, by definition, put down as an overall shortage.

The pitfalls that attend manpower forecasting, in the case of the highly qualified at least, now seem to have been squarely faced in the UK, and the government no longer sees any need to do further 'requirement surveys', at least on such wide categories as 'scientists', and its whole approach to the collection of statistics (without using them to make forecasts) now seems much more geared to the highly qualified in general than to scientists in particular. After all, scientific manpower forecasting in the 1960s was, as Gannicott and Blaug put it, "a science lobby in action".

It used to be the case (for engineers as recently as seven years ago) that the salaries of scientists and technologists increased at a higher rate than did the remuneration of other workers² (see Table 1). In that sense, the position of scientists has long since reached a high point, and has subsequently deteriorated. Even the scientists' 'stature' among the highly qualified—those with at least a first degree or equivalent—has diminished while that of the social scientists, for example, has improved according to this criterion.

Economists would therefore have it that the UK is awash with scientists and that a surfeit of chemists can be traced back to seven or eight years before 1972, a year in which the uptake of graduates of all kinds by industry tailed off so

Table 2 Number of people with university degrees in employment (million)

	Total	Degrees in science and technology	Degrees in science and technology as a percentage
United States	5.170	1.106	21.4
EEC (the Six)	2.175	0.711	32.7
UK	0.662	0.250	37.8
EEC+UK	2.950	0.961	33.9

dramatically. (In that year employers recruited some 2% fewer graduates, at a time when 7% more were available; the situation improved in 1973, however, when 15% more posts were on offer to 5% more graduates.)

One result of the 1972 debacle is the phenomenon of the chemistry department with almost as many staff as students—an over-reaction by prospective students to an over-reaction by employers three years before. This is almost certainly a short-term effect obscuring a longer-term trend towards an increase in "qualification density" (the proportion of people within a given group with a given qualification) in Census employment classifications like "Administrators and Managers", which accounted for 10% of all graduates or their equivalent in 1966. The qualification density for technicians went up by leaps and bounds in the 1960s; in 1965 14% of them were graduates, but by 1968 the proportion was 22% (ref. 2). And undoubtedly the long-term trend is still continuing, in spite of indications that at the moment industry is crying out again for the products of almost empty chemistry departments.

Whether or not the increasing qualification density in non-traditional graduate jobs will eventually prove the case for more opportunities in higher education to take broadly based degree courses and for the rapid growth of the polytechnic programme at the expense of the universities, the trends in scientific manpower during the 1960s and early 1970s cast considerable doubt on the accuracy of manpower forecasting.

Europe

From a more international standpoint, the OECD has also come to similar conclusions about the usefulness of manpower forecasting for the highly qualified. The organisation was actively interested in matters concerned with scientists, technologists and engineers (see Table 2) in the late 1960s and early 1970s, and it produced, for example, its famous set of reports on *Gaps in Technology* between member countries, one of which deals extensively with manpower statistics but eschews manpower forecasts. The OECD effort culminated in a conference in Venice in 1972, which concluded that fears about the consequences of overproduction of qualified manpower (overproduction was the *bête noire* at that time) were unfounded on the grounds that it would not be any real hardship for some of the highly qualified to look rather further afield for longer before getting a job. Nevertheless there was a general awareness that it would be helpful to have a better understanding of the relation between the needs of industry for graduates and the output of the higher education system.

Table 3 Swedish industrial planning, 1965

	Increase in industrial output per year (%)	No. of industrial employees	Density of engineers (%)	Forecast no. of engineers
Original forecast	3.5	961,000	4.68	45,000
Revised forecast	6.0	1,074,000	5.85	62,800
Actual no.	—	—	—	53,800

Table 4 Actual and predicted employment of scientific and technical personnel in France, 1954–78 (thousand)

1954 actual	1962 actual	1970 forecast on hypothesis*				1978 forecast
		1	2	3	4	
460.4	617.8	729.4	868.9	1,009.0	933.5	1,307

* Actual figures for 1970 not available.

There are no moves afoot on the part of OECD members to look again at the question of highly qualified manpower—a fair indication that most countries do not now see it as a problem area—but higher education is going to be examined further from the point of view of both research and teaching. In the latter case, the eventual recommendations are bound to reflect the pressures to widen higher education and increase the scope for more flexible and broadly based courses. The question of university research is likely to prove a more thorny one, however, with countries asking whether universities are losing some of their status as research institutions.

The European Commission in Brussels is also interested in highly qualified manpower, but mainly from the point of view of migration within Europe. A study was launched last year but the outcome is not likely to be clear for a while yet.

Sweden and France

Swedish experience in manpower matters is particularly interesting because Sweden has a relatively small population, has a relatively 'interventionist' Labour Market Board, and in 1969–70 spent 3.7% of total public expenditure on employment services compared with 0.57% for the UK. Here, it seems, is a country which is notionally in a good position to get its sums right. And yet manpower forecasting as a long-term exercise has not been regarded as much of a success there.

An example which seems to typify the situation is a forecast made in 1957 of the number of engineers required in 1965. The results¹ are summarised in Table 3. The calculations were based on a number of premises derived from data for the previous 20 years, in the main involving assumptions such as that the proportion of engineers in the labour force would continue to increase at a rate which could be predicted from the 'historical' behaviour. In the event the projected increase in output was wrong, as was the estimate of the total number

of employees (by 10.5%). The estimated number of engineers was thus 18% low, but what is more interesting is that even if the data had been correctly predicted the forecast number would have been about the same percentage too high.

In France, manpower forecasting is tied up with economic plans, and a feature of the techniques used is that at the various stages of production of the plan no single model is used; opinions and judgement come in at every stage and iteration is allowed to ensure that manpower forecasts are consistent with other economic indicators. A hotch-potch, one might think, but one in which the straight manpower-requirements approach (setting an economic goal and working towards it in a rather blinkered fashion) is leavened with a little old-fashioned experience.

Table 4 shows some salient figures for 1954–78. The four hypotheses mentioned range from a minimum assumption (1) to a maximum assumption (3). In the hypothesis adopted (4) the occupational structures in various sectors were based on the opinions of the various planners.

Success or failure?

Although the present techniques of manpower forecasting leave much to be desired as far as predictions in the long term are concerned, over shorter periods of two or three years better results ought to be possible. Unfortunately short-term forecasts that are updated and corrected every year, say, are of relatively little use in educational decision making because of lags built into the education process. On the other hand, accurate short term forecasts could form the basis of a continuous rather than a sporadic source of manpower data; in addition, more needs to be learned about the relationship between the requirements of industry for graduates and the output of the educational system. These could be used as the basis of ongoing policy modifications—if indeed the country concerned actually has a manpower policy at all—or, more important, as the first step towards persuading industry that a severe cut in the number of highly qualified people taken on in one year, followed by a huge demand a year or so later, is of no advantage to it in the slightly longer term and unnecessarily disruptive of the educational system back through the universities and into the schools.

¹ *The Practice of Manpower Forecasting* (edit. by Ahamad, B., and Blaug, M.), (Elsevier, Amsterdam, 1973).

² *Employment Prospects for the Highly Qualified*, Manpower Paper No. 8 (HMSO, London, 1974).

Training for British participation in the North Sea

Eleanor Lawrence

Specialised graduates in the fields of petroleum geology, geophysics and petroleum engineering will be needed to man Britain's participation in the North Sea oil industry. Three universities in Britain have been identified as the centres for the necessary training effort. This article reviews the progress made so far.

TWELVE months ago, the government directed the University Grants Committee to set aside some £300,000 over the next 3 years to the end of the quinquennium, specifically to finance petroleum-related courses in three British universities, Imperial College in London, and Heriot-Watt and Aberdeen in Scotland. This unprecedented commandeering of UGC money for a specific purpose followed a 1973 report by a working party of the Training Services Agency (a department of the Manpower Services Commission) on Education and Training for Offshore Development which identified possible shortfalls in the numbers of trained British scientists (geologists and geophysicists) and engineers available to work in the North Sea oilfields.

In the discussion on possible shortfalls, the distinction must be drawn at the outset between non-specialist geologists, geo-

physicists and engineers, and those with an academic training specifically directed not only towards the theoretical aspects of petroleum studies but also towards the sort of practical problems they will have to solve in industry itself.

There is certainly no shortage of geologists *per se*—many people see an overproduction—but petroleum geologists or explorationists are rare—(especially those with a practically orientated training). Engineers graduating with a first or even a masters degree in petroleum engineering also form a relatively small proportion of the total engineering output, but in this case there is also a growing shortage of good engineers of any persuasion.

In the past, the lack of specialised training did not seem to pose many problems. At the time, the large oil companies on Britain's doorstep, Shell and BP, preferred to take non-specialists and train them within the company through their extensive, well-established training schemes. What specialised courses there were at British universities either disappeared, as did the petroleum engineering course at Birmingham, or survived by taking in a large proportion of foreign students. But with the increased activity in the North Sea, the situation has changed somewhat. Many of the companies operating in the North Sea

are essentially foreign-based—American companies wishing to replace their American personnel with British graduates and companies operating far away from home-based training schemes, with limited on-the-spot facilities, are now in the market for both specialised graduates and post-experience training facilities in petroleum geology and engineering. Small British oil companies such as those constituting Brindex will need considerable numbers of exploration geologists, production geologists and engineers if they are to help exploit North Sea oil.

The apparent shortage of British petroleum engineers and geologists to work in the North Sea is not, however, simply one of under-production. Imperial College, for instance, has been running oil technology courses in its geology department in the Royal School of Mines since 1913 and there are many highly qualified and experienced British geologists and engineers in the oil industry throughout the world. One of the problems, according to Professor Colin Wall, the head of the newly-established Section of Petroleum Engineering at Imperial College, is that conditions of employment for competent qualified petroleum engineers are much better abroad where the tax position is far more favourable. So the training effort must be adjusted to take account of this wastage. Imperial College and Heriot-Watt have been designated as centres of petroleum engineering and Aberdeen as a centre of petroleum geology. Professor Arthur Whiteman, the new head of the section at Aberdeen stresses that they are concerned not simply with petroleum geology but with the problems of petroleum exploration geology and geophysics, a very different approach. Petroleum geology as taught as a component of many geology courses tends to concentrate rather on the academic and theoretical aspects and certainly does not provide the applied viewpoint which an exploration geologist working for an oil company, or for one of the independent contractors, will need.

In all the centres the one-year MSc course has been chosen as the main academic training vehicle, although undergraduate courses are being or will be offered as well. But the general view is that a one-year course offered to slightly older students who are committed to a career in the oil industry will produce better results more quickly. Heriot-Watt's new MSc course in petroleum engineering for about 20 students is due to start this year. It will be taken within the Institute of Offshore Engineering, which was established in 1972 with a grant from the Wolfson Foundation for training and research in all aspects of constructional engineering for the North Sea. As well as the MSc in petroleum engineering, the Institute will offer an undergraduate course in Offshore Engineering (the first students will start the full 4-yr course this year; it has been offered as a final year option for the past few years). But in the short term, probably the most valuable contribution the centres can make, is in the short post-experience courses they offer to staff already employed in the industry. Imperial College has run two such 10 day courses already, for a total of 21 people and hopes eventually to cope with about 50–60 students of this type each year. Already the British Gas Corporation, Conoco, Core Labs, the Department of Energy and Shell (UK) Expro have made use of these courses. The Section of Petroleum Geology will also be running such courses shortly.

Even when full-time courses are provided, it does not automatically follow that it is easy to find British students to fill them. On Imperial College's MSc course in petroleum engineering for 1974–75, only 5 of the fifteen students were British. The remainder came mostly from oil-producing states such as the Middle-East countries, Nigeria and Australia, financed by oil companies operating in these countries.

The situation is different for undergraduate students, most of whom are British. This imbalance arises in great measure from the difficulty which British students find in obtaining grants to do postgraduate work, a situation which is unlikely to change without special help. The Geology Department at Imperial College has no shortage of applicants for its long-established MSc in petroleum geology (which has not been

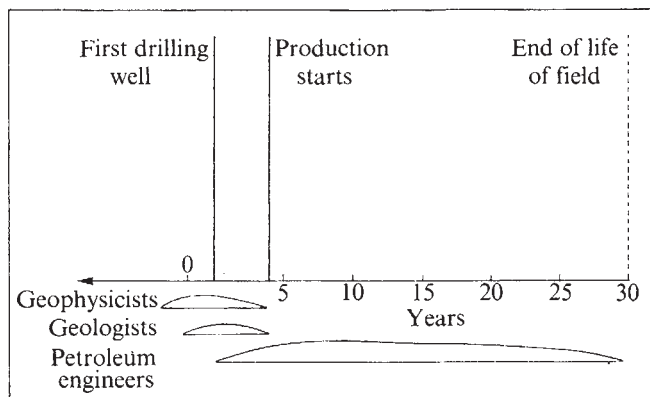
allocated special UGC funds). This year only about one in every five applicants will get a Natural Environment Research Council grant. British students can no longer afford to study at British universities and the vacant places will be filled by students from the Middle East on petro-dollar supported grants. Even when studentships are available, as at the new course at Aberdeen, there is still difficulty in attracting students. Professor Whiteman considers it hard to attract students to a grant-aided course, because at the moment a good first-degree graduate can join an oil company and be paid between £2,000 and £3,000 within his first year.

This situation may be changing, however, as the downturn in straight oil exploration activity this year may mean fewer opportunities for the non-specialist. This downturn has also been experienced by the Geology Department at Imperial College which saw five out of nine oil companies cancel the routine 'milk-round' interviews this year. But the picture could change almost overnight. The downturn has been variously attributed to the stabilised price of oil, the British Government's policies of participation and the proposed Petroleum Revenue Tax. If circumstances change there is still a great deal of worthwhile exploration to be done both in the North Sea and off the western coasts of Britain and Ireland.

These factors highlight the difficulty of forecasting manpower requirements in this field, especially when the personnel take at least three or four years to train through a first degree course followed, perhaps, by a specialised masters degree. In the life of an oilfield, different qualifications are needed at different times (Fig. 1). The survey geophysicists and geologists come in first, exploring for structures which might contain oil. When the first exploration well is drilled, the production geologists and the petroleum engineers must decide whether it is worth developing; hundreds of millions of pounds can rest on their interpretation of the results from a few tests on the one well. Petroleum engineers are then needed throughout the life of the oilfield, but the geological and geophysical exploration effort slackens off on that particular field—perhaps less quickly than usual in the North Sea, where conditions are novel and sometimes unstable. Reservoir or production geologists are frequently needed in the development and production phases of an oilfield.

In the present round of North Sea development the peak requirement for geologists and geophysicists has now been reached. Their main field of operation will now move to the western basins (Celtic Sea and West Coast of Scotland), although another round of licensing in the North Sea could lead to an upswing of activity there. Shell (UK) Exploration built up over the past ten years from 0–66 petroleum engineers, 0–43 geologists and 0–25 geophysicists. The demand for geologists and geophysicists has now reached its peak and the present numbers will be kept steady over the next two years

Fig. 1 Diagram indicating qualitative manpower requirements during the life of an hypothetical oilfield. Production geologists are also required later on in the life of the oilfield.



with a recruitment of about four people in these categories each year to keep successions moving; but a further 15 petroleum engineers will be required.

Courses were not ready to meet the sudden demand for specialised geologists and geophysicists needed for the original North Sea oil breakthrough, because it was simply not foreseeable in time. The Aberdeen MSc course in petroleum exploration studies, now in its second year, is producing five students each year, which could be increased to ten if suitable candidates could be found. With increased financial support over and above the £15,000 per annum provided by the UGC for the three years from 1974, 20 students could be accommodated, but a capital grant for equipment and buildings has not yet been forthcoming although negotiations have been opened with the Department of Energy for more funds.

About 20 students each year take the MSc in petroleum geology which Imperial College has offered for many years; Dr R. C. Selley of the petroleum geology section estimated that a production of about 50 from all UK sources each year could be absorbed into the industry if the economic conditions were right and exploration activity was on the upswing again—this also allows for those going overseas to work.

Although the situation does not look particularly promising for geologists and geophysicists at the moment, the training efforts must be started and sustained now, otherwise Britain is going to be unable to supply the necessary specialist manpower for the next round in exploration. Nobody has yet any idea what range of exploration will be needed. At present, operations around British coasts are confined to the relatively shallow continental shelf. Eventually, the effort may move out into the deepwater Atlantic, off Rockall and off the west coasts of Scotland and Ireland and into more difficult areas of the North Sea where new "plays" must be developed.

One of the few attempts to estimate the numbers of qualified scientists and engineers needed for the North Sea operations up to 1980 was made by the Manpower Services Commission in the course of a report dealing with the whole problem of manpower for North Sea oil and related industries, published early this year. Their estimates were based on figures supplied by the Petroleum Industries Training Board, who took the numbers of geologists/geophysicists/engineers needed to man each seismic survey vessel, drilling rig or platform, and then projected these figures on estimates of exploration, drilling and production activity up to 1980. But this sort of forecast can be notoriously inaccurate as activity changes with the economic wind.



the model. The opportunities for British graduates could then be pinpointed for at least some years ahead and the training programmes adjusted appropriately.

Britain's need for scientists and engineers qualified in petroleum studies is not simply restricted to the North Sea operations of the oil companies. The Department of Energy, the Scottish Development Department and the Offshore Supplies Office, for example, all need qualified, experienced expertise if they are to direct Britain's participation in the oil boom intelligently.

Some recent estimates put the number of those with technical (as opposed to economic) qualifications in oil-related topics in the Department of Energy, at about 30. The Offshore Supplies Office has a total staff of 90 but very few technical specialists, and there is a general lack of industrial experience. At the Institute of Geological Sciences, of a total staff count of around 1,000, about 60 are concerned with the geology of the North Sea as it relates to oil and of these, only about 40 are directly concerned with the actual geophysical and geological data coming out of the North Sea through the oil companies.

The Gas Council has been involved in North Sea operations for a long time now and has a good exploration department including around 20 scientists and engineers; but the National Coal Board, whose interests in the North Sea will be taken over by the proposed British National Oil Corporation, has an oil department of 13 including only three people with direct exploration and other technical expertise. The British National Oil Corporation will also require qualified manpower soon. If this company is to develop into a fully-fledged working oil company and not simply the state holding company, British technical specialists will be needed urgently.

Some idea of the scale of manpower needed in the operation of a large oil company is given by BP's figures for its North Sea operations. It employs around 350 technically qualified professional staff at its UK Continental Shelf Offices with a back-up of some 145 technical staff in London. Its Forties Field operation alone employs 50 technical staff plus 100 support staff at headquarters. Conoco's exploration and production division in the United Kingdom employs about 330 technically-qualified staff.

So although the North Sea operation itself is hardly likely to collapse through lack of manpower, if Britain wants to build up a body of qualified, experienced oil men within the United Kingdom, the training programme is very necessary although the blockage is likely to occur even before entry to the specialised training courses. The oil industry seems to be unattractive to young people, according to Professor Wall. They see it as a foreign-dominated, multinational giant. Coupled with the general swing away from science and industry apparent among school-leavers, this is probably the greatest threat to Britain's full participation in the oil industry now on her doorstep.

Table 1 Estimates of some selected categories of manpower needed for offshore operations in the North Sea

	1973	1976	1980
Professional grades (total)	1,315	1,785	2,320
of whom:			
Geologist/geophysicist	440	485	520
Petroleum engineer	190	280	330
Production engineer	210	320	440
Drilling engineer/toolpusher	240	370	465

1973 figures are actual survey figures collected from the oil companies. These figures relate only to men actually employed on offshore operations. The MSc training courses in petroleum engineering will produce graduates qualified as both production and petroleum engineers in the categories above and the petroleum exploration studies course will provide both geologists and geophysicists.

A sounder basis perhaps for forward planning, in the estimation of one North Sea watcher, would be a comprehensive census by category and nationality of all scientists and engineers working at present, not only in the field but in the UK headquarters of the companies. Extrapolation of trends such as the 'de-Americanisation' of the American-based companies operating in the North Sea and natural wastage could be built into

Use of manpower in Japan

from a Special Correspondent

Because of the unique structure of Japanese society, discussions about needs for qualified manpower have only recently started.

BROADLY speaking, the way Japan uses her scientific manpower is unique because three crucial concepts are involved: one can call them cooperation, security and self-help.

The first embodies the fact that the boundary between the public and private sectors is more blurred in Japan than elsewhere. Japanese society, as is well known, does not encourage individualism and, moreover, industrialisation in the 19th century was the result not only of private enterprise but of deliberate government policy. Another feature, perhaps a result of all this, is that there has been very little public debate about the need for trained people. This situation is now changing, at least partly because the slow-down in the growth of the economy is causing problems. The outcome of the debate is uncertain, but it will certainly be a consensus of the views of universities and public and private interests. It would be an impossible, and meaningless, task to say which particular idea came from where.

The second refers to the security of jobs in Japan, which is usual at all levels of society. Mid-career transfers between sectors, or even between companies, are rare. Within each organisation, whether company, ministry or university, promotion is commonly determined far more by seniority and far less by merit than in the West, and it is loyalty rather than the prospect of promotion that provides the incentive to work.

The third concerns the extraordinary diligence and academic ambition of Japanese schoolchildren and their parents. Although fees are charged for schooling above the statutory minimum school-leaving age, 90% of children do stay on and a third of them go at great expense to a university.

Since the war Japanese education has been organised along the lines of the American framework. Standards, on the other hand, seem to be much more European and university entrance papers are much more reminiscent of British scholarship papers. For example, schoolchildren intending to study science learn

differential calculus as far as simple differential equations, while still at school. (This is in spite of two handicaps under which all Japanese children labour: first, literacy in their own language entails the memorisation of at least 2,000 Chinese characters each with at least two pronunciations, and they have to be able to read and write English, which is taught to an extremely high standard but rather formally as though it were a dead language).

The boom in university education has produced an immense number of private universities. These are no entrants' first choice, for they lack the reputation of the older state universities and are much more expensive. The boom began in 1967 when 26 universities and 55 junior colleges were established. There are now 304 four-year private universities, 434 two-year private universities and seven private technical colleges. Altogether they make up about 82% of colleges and universities in Japan.

There is now much concern about the quality of these institutions and, it has to be admitted, about the quality of the students they accept. The decline in the proportion of students wishing to specialise in science has been greeted with private relief in some government circles. A White Paper published last year emphasises the need to establish close cooperative relations between government and existing institutions to coordinate innovations. The fact is that up to the present time there has been no study made on the question of how many high school graduates should go on to university.

In the middle of March 1975 the Ministry of Education published an ordinance revising the criteria which a proposed institution must fulfil in order to be approved. This is, however, only a step towards more concerted coordination. The new criteria are (1) geographical location—the ordinance seeks to halt the centralisation of universities in Tokyo Metropolis and the three neighbouring prefectures, and (2) financial fitness. The background to the latter provision illustrates one of the problems of a 'lobby group' style of government. Medical and dental schools traditionally raise capital by requesting donations from applicants for admission. It seems to be the present intention to discourage this practice by removing the need for it. This is partly the result of widespread allegations

Table 1 Holders of higher degrees from Japanese universities (1972)

Subject	Master's degree (two years post-graduate)	Doctor's degree					Total
		Old system*	National universities†	Public colleges†	Private universities†		
Literature	20,032	1,636	381 (319)	14 (5)	249 (213)	644 (537)	
Education	2,851	—	167 (116)	—	1	168 (116)	
Theology	1,245	3	—	—	10 (5)	10 (5)	
Fine Arts	1,507	—	—	—	—	—	
Social sciences (including law, economics and commerce)	19,495	1,598	501 (324)	32 (28)	283 (187)	816 (539)	
Science	15,881	5,830	5,513 (2,559)	397 (302)	182 (84)	6,092 (2,945)	
Medical science	3,683	70,590	18,338 (9,358)	3,314 (1,823)	7,801 (4,611)	29,453 (15,792)	
Engineering	39,960	6,715	5,562 (2,784)	307 (179)	557 (308)	6,426 (3,271)	
Agriculture	7,386	3,287	2,718 (1,686)	45 (20)	145 (105)	2,908 (1,811)	
Veterinary medicine	459	116	60 (41)	—	117 (92)	177 (133)	
Fisheries	392	82	67 (48)	—	—	67 (48)	
Total	112,891	89,857	33,307 (17,235)	4,109 (2,357)	9,345 (5,605)	46,761 (25,197)	

*Old system and †new system: before 1945 doctorates were awarded by the German system. Since then they have been awarded either by examination including a thesis after three year post-master's degree attendance at university or by a thesis only extra-murally. Total numbers awarded are shown with the latter method in brackets.

that this practice has led to unfairness in selection, and even in success in final examinations. These allegations have represented many people's private opinions for several years—it is one of those things that 'everybody' knows but has only recently come to the surface. A headline in the *Mainichi News* of April 5, 1975 reads "30 million yen not enough" and the newspaper alleged that medical examinations at a leading university are completely rigged and that the going rate for entering this lucrative profession has now passed 30 million yen (about \$100,000). The power of the medical lobby is seen, incidentally, in another way: doctors and dentists are allowed by a widely resented law to claim up to 90% of their gross fees as expenses and so pay no tax on incomes of typically 10 million yen.

Whatever the truth of that, non-medical graduates have the usual options of staying on for higher degrees or joining government or industry. Table 1 indicates the numbers who can and do opt for the first alternative. The difference between

Japan and the rest of the world is that if the present system of 'life-long hiring', as it is called, survives the slow-down in economic growth that has sustained it for nearly a century, then the decision will continue to be a commitment for life. The system has come under strain in the past year. A distinguished professor of industrial sociology, Hiroshi Hazama, defended the system recently in *Chuo koron* magazine on the grounds that the extraordinarily high population density of Japan makes American-style competitiveness exceedingly undesirable, for it would raise stress to an intolerable level. He criticised the few companies which have introduced this policy in the last decade. The lack of competitiveness in the private sector probably accounts for the fact that it enjoys in graduates' minds neither less prestige than the public sector, as in Britain, nor more as in the USA. And certainly there is no sign of competitiveness in the public sector. Not only does the government pay all its scientists the same; it pays them the same as lawyers and economists.

Israel at the crossroads

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A small country engrossed in the problems of immigrant absorption, Israel could either limit its responsibility for the growth of her exploding academic personnel, or risk a breakthrough in a new kind of scientific manpower.

WHEN Jewish pioneers left Eastern Europe in the 1920s and 30s and immigrated to Israel, they sang the then most popular song "We've come to this land to work it and to be redeemed". Most of them had forsaken well-to-do homes and were members of various Socialist-Zionist Labour Movements. Through this song they tried to express their desire to cut themselves off from the traditional Jewish scholarly philosophy which despises physical labour. In this ancient-new land of theirs they wanted to recreate a new brand of Jew, who works on the land and engages in hard physical work. They succeeded in building Kibbutzim, villages and towns; they developed modern agriculture and industry, but they could not detach themselves entirely from their past.

The first big wave of modern Jewish immigration to Israel came after the First World War. When these pioneers arrived in Palestine they did not find a large Jewish population nor did they find a Jewish State. But there were already two academic institutions; the Technion in Haifa and the Hebrew University of Jerusalem; the first laid its foundation stone in 1912 and opened its gates to students in 1924 and the second in 1918 and 1925 respectively. Thus the history of scientific manpower in Israel preceded the establishment of the State of Israel by about a generation. The Jewish population of Palestine in 1925 numbered about 122,000 out of a total population of 800,000.

Outstanding position in science

Israel is one of the smallest countries in the world, but it occupies a disproportionate place on the scientific map in relation to its physical size. At the end of 1973 the population of Israel was about 3.3 million, of whom 2.81 million (85%) were Jews (about 19% of the total number of Jews in the world).

In 1973 the civil working force of the country comprised more than one-third of the total population and numbered 1.088 million. Of the total working force, 41.8% were employed

in industry including construction and communications; 37.4% in public and private services; 12.7% in commerce; 7.3% in agriculture and fishing. The numbers employed in agriculture have been decreasing slowly but steadily from 17.5% in 1955 to 7.3% in 1973. The number of professional, scientific, technical and related workers in 1973 was about 17% compared with about 16% in 1972 and 11.3% in 1960. The expansion of industry, construction and the Civil Service was accompanied by a process of professionalisation in many occupations. Israel has the largest proportion of professional, scientific, technical and other related workers in relation to its total population and the second largest relative number of people with academic degrees in the Western World.

Of the greatest interest, are the various factors responsible for the rapid growth of scientific and technological manpower in Israel, namely the number of scientists and engineers engaged in research and development (Table 1), the development of higher education in Israel and the 'brain gain' through immigrating professional personnel. It is also interesting to note the very high student population ratio in Israel (second only to the United States and Canada) which indicates an intensive academic programme, and the relatively high investment in research and development (Table 2).

Higher education

From their onset the institutions of higher learning in Israel have established very high academic standards. Today there are seven universities in the country which grant degrees at all levels, PhD included. All put strong emphasis on research.

Table 1 Scientists and engineers in civil research and development in Israel

Sector	Total	Full-time equivalent
Total	5,400 (est. 1974)	3,350
Government	800	700
Institutes of higher learning	3,300	2,000
Industry	1,300	650

Preliminary estimates. Sources: National Council for Research and Development, Prime Minister's Office, Jerusalem; Central Bureau of Statistics, Jerusalem.

Table 2 Allocations for research and development in the civilian sector

Sector	Source of Funds (1973)			
	Total	Government	Institutes of higher learning	Industry
Total	507	297	128	75
Government*	88	86	—	2
Institutes of higher learning	314	185	128	1
Industry	95	23	—	72
Hospitals	10	3	—	7

Preliminary estimates in millions of Israeli lira.

*This sector covers almost all of the research institutes in Israel. Sources as in Table 1.

Government budget, financial year 1973/74 (IL million) 19,800

Total GNP, 1972 (IL million) 28,958

Gross output value in industry, 1972 (IL million) 17,302

Government allocations for research and development

(1) Civil research and development expenditures in natural sciences and engineering, 1973 (IL million) 507

(2) Civil research and development expenditures in industry, 1973 (IL million) 95

(3) Civil research and development expenditures in industry as percentage of gross output in industry, 1972 0.55

(4) Research and development expenditures in universities, 1973 (IL million) 314

Source: ref. 2.

These institutes also serve as major links between Israel and the world Jewish community by making Israel a cultural centre of world Jewry and by attracting students and scholars from abroad.

Forty per cent of the 50,000 students and graduates in 1973 studied science and mathematics, engineering, agriculture and medicine. The accelerated growth of higher education has been caused by the rapid growth of intermediate education. Recently, pressure from school-leavers has caused a reaction in the universities reminiscent of the development in Europe, where the expansion of Social Sciences and Humanities faculties has occurred.

The academic system in Israel is the major supplier of manpower for research, academic teaching and other scientific or technological employment in the country in spite of the large 'brain gain'. During the past few years about 6,000 students graduated annually from the academic institutions and about 4,000–4,500 academicians came into the country; thus the academic population of Israel increases annually by about 10% (Fig. 1).

In addition to the rapid expansion of academic education there occurred recently in Israel a rapid development of semi-academic education, particularly in teacher training, but also in technical and other professional fields. In 1973 there were about 21,000 pupils in post-intermediate education comprising courses in teacher training, practical engineering, technical work, and paramedical occupations.

Israeli universities are autonomous and independent institutions. But they receive over 80% of their operating funds from the public, be it the Government, the Jewish Agency or support from abroad.

Dynamics of research and development

Table 3 reveals the very rapid growth of the scientific establishment in Israel. National emphasis has been put on basic research, which is considered to be "elite" research. This attitude has its roots in the traditional Jewish approach to learning and it has been responsible for the fact that over 60% of the non-defence research conducted in Israel is performed in academic institutions. The assumption has been that science is instrumental for technological and industrial advance. Therefore, university science should be a major factor in starting off technological innovation and promoting the

growth of science-based industry. This emphasis on academic learning has resulted in the neglect of applied research both in the universities and in government research institutes. Dr S. Wald has written that "Israel appears to be the last bulwark of the old faith: an attitude which puts theory and pure science above practice and application has until very recently pervaded everything in the civilian sector, Industry, University, Government and public opinion"¹.

Israel's culture is predominantly European. Therefore the economy demands highly skilled and educated personnel. In the absence of important raw materials it is clear that future economic growth will have to come from those industrial sectors which need skills, engineering and applied research. But the high rate of government allocations to basic research, the inability of local industry to undertake sizeable research and development of its own, coupled with the tendency of universities to shun cooperation with industry and applied research, underline the special responsibility of the government in Israel towards development.

The percentage of the gross national product which is allocated to all forms of research and development is very high in Israel (2.4%; second only to the United States). Table 4 illustrates the very high government participation in funding research and development in Israel.

The rate of government allocations to university research and development in relation to its allocations to other sectors is very high (59%); government participation is lower in most western countries and only in Japan it is slightly higher. Table 2 shows how small is the scope of industrial research in Israel compared with university research.

Between 1969 and 1972 most of the academic graduates were absorbed in the universities, as researchers or teachers. During those years, the growth rate of universities in Israel exceeded the growth rate of intermediate education. The high value placed on pure science has had other consequences; the relatively low status of engineers compared with scientists, the lower status of industrial employment compared with university employment, and a greater attraction to pure science,

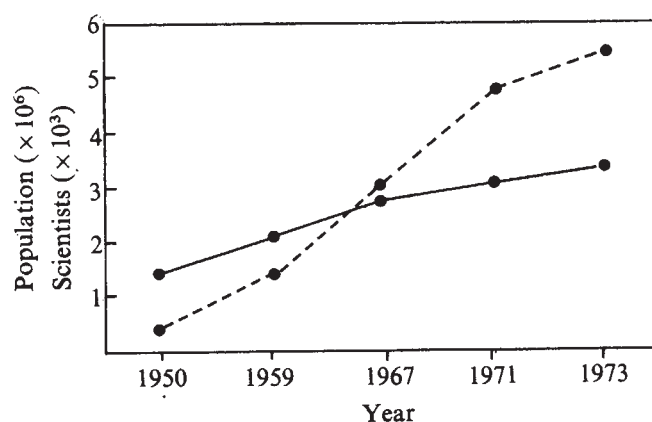


Fig. 1 Comparative growth of population and scientists in Israel. —, Population; ---, scientists.

mathematics and medicine rather than engineering. These facts coupled with the relatively small size of Israeli industry, mean that industry will not indulge in a large research and development programme nor employ a large number of academic and technical personnel. And last but not least, until several years ago the universities were reluctant to get involved in applied research and they are still slow in developing intellectual and practical links with industry. It is characteristic of industrial countries that their industry is able to finance its own research and development. Whereas the value of industrial

Table 3 Growth of science in Israel, civilian sector

	1950	1959	1967	1971	1973	Rate of growth (%) 1950-73
Total population (in thousands)	1,810	2,000	2,660	3,095	3,307	2.8
Scientists and engineers engaged in civil research and development	400	1,400	3,000	4,800	5,400	13.5
Research institutes	15	32	54	60		
Academic institutes	2	5	7	7	7	3.5
Students	1,800	9,800	28,000	40,000	50,000	27.7
PhD degrees in natural sciences, agriculture and engineering (Medicine excluded)	10	91	123	236	277	27.7
Allocations* for civilian and university research and development			128	200	507	

*In millions of Israeli lira.

Sources: refs 3 and 4.

production against gross national product in Israel is now approaching the ratio obtaining in developed industrial countries, total national allotment to research and development in industry as a percentage of total national allotment to civil research and development is more than three times lower in Israel than in developed countries. This situation places Israel nearer to the group of developing countries than to the developed ones.

Why a central scientific manpower policy?

The assumption that rapid economic and industrial growth is correlated with accelerating technological development is deeply rooted in Israel. But the expansion and rapid development which prevailed in the country after the 1967 war has been fading since 1972. The world economic crisis has drastically diminished foreign investment and financial help to academic institutions. There have been signs of latent unemployment among professional persons. The government is being forced to take a stand and pursue a central policy of scientific manpower as a result of its heavy commitments to research and development and because of the approaching crisis in the scientific manpower labour market. The institutions of higher learning annually produce about 300 PhDs, thus increasing their number by about 5% every year; in addition one has to consider thousands of Israeli academics abroad, 500 of whom try to return to Israel each year, and the immigrant 'brain gain'.

There has been a positive development in government approach to the problem. The Ministries of Defence and Agriculture have been alert to the situation for some time; other ministries are in the process of creating the tools to cope with it. The National Council for Research and Development (NCRD) has crystallised the two basic inbred weaknesses of the scientific situation in Israel; the imbalance between the efforts of basic research and those of applied research and technological development; and the imbalance between available good scientific and technological manpower and its use in suitable jobs. NCRD has also outlined two primary

missions which the government has been advised to put top of its list of priorities within the framework of the national science and technology policy. The government should intensify applied research and development efforts and enhance their quality, to turn them into a valuable tool to aid the solution of economic as well as absorption and social problems; and it should coordinate all operational schemes and investments in science, technology and higher education in Israel, to achieve a proper relationship between the creation of knowledge and production of scientists as well as between the use of this knowledge and the creation of suitable jobs for the pool of scientific manpower.

To tackle these missions, the Israeli Government has set up a Ministerial Committee for Science and Technology and has also set up interim bodies to assist in solving operational problems in the various ministries; such bodies are the offices of Chief Ministerial Scientists, various advisory and executive agencies, the University Grants Committees, as well as various scientific services, such as the Center of Scientific and Technological Information and the Center for Absorption in Science. Operating such bodies requires a certain budget, and the government is preparing a National Budget for Science.

In this context it is important to note a new trend which has been pursued in the universities, on the initiative of the Center for Absorption in Science, with the aim of searching for new organisational forms to absorb scientists. These are scientific groups which aim at developing the nuclei of research organisations, production companies and various services based on research and development. These groups will liaise between universities and industrial centres, science-based industrial parks near universities, research institutes and new research and development groups (with many new immigrants). These bodies have been designated to explore new scientific and technological fields worth developing, without any commitment to maintain them or their personnel after their term expires.

Thus there is a national urge to support and promote science. But there is an obvious lack of precise definition as to why such support is good for the country; and there is a lack of a central research and development policy, making the best use of available manpower. Academic manpower can be a great force when properly used.

Great expectations

The era of sporadic development is over. Both the academic establishment and government officials have come to realise that a crisis is possible not only among blue-collar workers but among academics as well. When such a crisis occurs it is necessary to reconsider which are the best employment alternatives for the available and projected personnel.

It seems that recent events have placed two alternatives before the government: either to let developments take their course, or else the government should face the challenge and use its enormous budgetary and tax measures to pursue a central scientific policy, which will focus on the academic manpower of the country and exploit its vast potential. If the intelligence and intellectual imagination of our people is the

Table 4 Government allocations in research and development (including Social Sciences), as percentage, of total expenditure in research and development

	Government participation in funding total research and develop- ment: civil and military	Government participation in funding civil research and develop- ment	Military research share of total government allocations (%)
Norway (1970)	58	56	6
Canada (1970)	54	51	11
France (1972)	50	42	28
Italy (1971)	41	40	4
W. Germany (1971)	39	35	15
Netherlands (1972)	38	37	4
Japan (1969)	14	14	2
Israel (1973)	> 70	59	> 40

OECD data, excluding Israel.

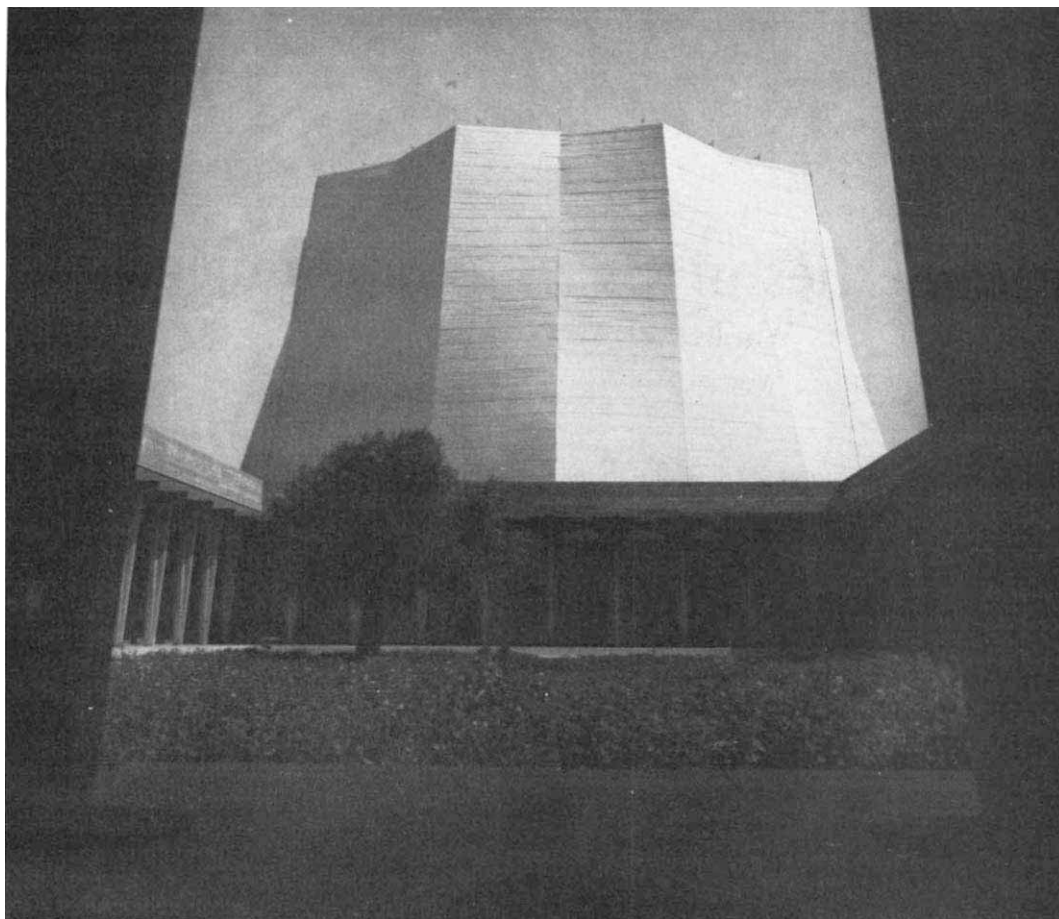


Fig. 2 Experimental nuclear reactor at Nahal Soreq.

main resource we have, then, this is what we have to develop.

Such an approach should attempt to create the proper climate for investing in science-based and other sophisticated industries; it should encourage institutions of higher learning to launch courses with the aim of producing not just more academics and technicians, but the kind of professionals needed for the desired industries. While pushing to create innovation centres in the universities, the government should adjust its financial support and tax incentive systems to benefit the more desired sectors of the economy; and last but not least: it should drive to create a new image for the scientist and engineer who work in applied research and industries.

The agricultural sector could provide a good example how successful cooperation between scientists, engineers and educated farmers brought about the fantastic achievements of Israeli agriculture. This sector supplies the country today with most of her essential foods, under semi-arid conditions and a severe shortage of water. It enables the settling of new and virgin land and consolidates a more balanced economy, diminishing Israel's dependence on imports. Between 1950 and 1970, agricultural production in Israel increased sixfold although the numbers employed in agriculture had decreased. In many commodities (such as wheat, cotton, milk and vegetables) Israel has reached world records per unit of production. These achievements were made possible through the application of experimental results to field conditions, introduction and development of new species and varieties, adopting modern methods and techniques—above all a joint effort.

Immediately after the 1967 war, Israeli extension officers aided Arab farmers in the occupied territories to introduce modern methods of soil cultivation, water use and food production. These extension officers were merely a small group among hundreds of Israeli scientists, physicians and technicians

who were engaged during the 1960s and the beginning of the 1970s in foreign aid, mostly to developing countries.

This agricultural model of developing new manpower through developing new occupations, to reap high quality achievements could serve industry and research and development services. Israel offers a particularly attractive climate for technologically intensive and research intensive industries. Not only do such industries enjoy high quality manpower, but they also have an advantage over most Western countries as salaries here are lower than in most industrial countries. Thus the cost of research and professional manpower is significantly reduced. Most science based industries in Israel are less than ten years old, but they already embrace a variety of fields and are developing fast. Another example of successful science-based industry is the military industry of Israel.

A well-defined central policy should aim at putting academic manpower at the top of the list of priorities; it should nurture such manpower in every avenue of life; it should create a general feeling of the importance of this manpower to the country and should attempt to provide every graduate student, immigrating scientist or returning scientist with an answer to the question—What kind of professional work could he do in Israel? This policy should also seek to develop the infrastructure and technology suitable to the small size of Israel and to her specific social and political problems.

¹ Wald, S., *Industry, Science, University in Israel: Opportunities and Problems of a Young Country* (National Council for Research and Development, Jerusalem, 1972).

² Hurvitz, U. and Yavne, M., *Statistical Indicators of Research and Development in Science Policy and Development, the Case of Israel* (edit. by Tal, E. and Ezrachi, Y.), (NCRD, Jerusalem; Gordon and Breach Science Publishers, New York, London, Paris, 1972).

³ Yadin, Dudai, *Scientific Research in Israel* (National Council for Research and Development, Jerusalem, 1974) (Hebrew).

⁴ *Statistical Abstracts for Israel 1974*, No. 25 (Central Bureau of Statistics, Jerusalem, 1974).

article

Radio properties of BL Lac type objects

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New radio observations of nine BL Lac type objects are discussed. It is shown that in their radio properties, these objects range from highly variable sources with a strong centimetre excess to non-variable sources with comparatively steep spectra. All the evidence strongly suggests that the most variable BL Lac type objects are extremely young.

SINCE 1970 we have been monitoring the flux and polarisation of 87 compact radio sources using the NRAO three element interferometer at $\lambda\lambda$ 11.1 and 3.7 cm. Among the sources observed regularly were several members of the class of objects similar to BL Lacertae^{1,2}. The radio behaviour of the better known BL Lac type objects seems to be characterised by large amplitude outbursts on very short time scales, and they seem to be extreme examples of the variable radio source phenomenon. We discuss the results of our own monitoring programme and compare the radio properties of BL Lac type objects with those of other variable radio sources.

Strittmatter *et al.*¹ give the main characteristics of BL Lac type objects as: (1) rapid variations in flux density at optical, infrared and radio wavelengths; (2) a spectrum such that most of the energy is emitted at infrared wavelengths; (3) no lines visible in low dispersion optical spectra; (4) strong and rapidly varying polarisation at optical and radio wavelengths. Here we consider BL Lac type objects as a class of optical objects without being prejudiced by their radio properties. Characteristic (3) is an insufficient definition since it includes various galaxies and white dwarf stars. Here we define a BL Lac type object as one that exhibits strong and rapidly varying non-thermal radiation at optical wavelengths and has a very small line/non-thermal continuum ratio.

There are at least 20 of these objects now known. In this paper we restrict discussion to the 10 objects known before March 1974. Since information on these 10 sources is scattered throughout the literature, a summary of relevant references is given in Table 1. Five of them (BL Lac, OJ287, 0048-09, W Coma, AP Lib) have been extensively observed by us for some years, and four others (4C47.08, 0912+29, 1101+38, 1215+30) have recently been added to our list and have been observed briefly. (The ten newest objects³⁻⁶ are now also being monitored regularly and will be discussed elsewhere.)

Spectra and flux variations

The radio spectra of the 10 sources are given in Fig. 1. The BL Lac type objects are not homogeneous in their radio properties. Although none shows steep spectra characteristic of extended optically thin sources, not all show the extreme centimetre excess of BL Lac and OJ287.

We find the usual correlation between centimetre excess and

degree of variability²¹. Of the sources we have observed extensively, BL Lac, OJ287 and 0048-09 show rapid large amplitude variations. Stull and Carpenter²⁸ found no evidence of variability for W Coma. We find clear evidence of variability, however, in particular in the polarised flux density but with a smaller amplitude and longer time scale than for the first three sources. AP Lib shows at most marginal variations^{31,32}. This is consistent with our own observations so far. Figure 2 shows our observations up to March 1974 of these five sources. The observing technique and detailed data will be given elsewhere.

Of the four sources added only recently to our programme, 4C47.08 has shown a large decrease in flux density at both λ 11.1 and λ 3.7 cm in only a few months and seems to be similar to the other sources with a strong centimetre excess. The sources 0912+29, 1101+38 and 1215+30 have shown no variations so far. These sources may be similar to AP Lib, although far more extensive monitoring is necessary to establish this firmly.

The remainder of this paper will be concerned with the four well studied variable sources (BL Lac, OJ287, 0048-09, and W Coma), and with a comparison of their radio properties with those of 21 other radio sources we have observed as extensively and which have also been found to be variable.

An unusual feature of the spectra of these four sources is that they have a positive spectral index over the whole range of wavelengths at which they have been observed. There is no sign of emission from optically thin regions that may be visible at long wavelengths. Such spectra are rare. In the compilation of 373 spectra by Veron, Veron and Witzel³¹, there are only two clear cases and five marginal cases of sources which are optically thick at both 10 GHz and 100 MHz. Most of the well known variable sources, such as 3C279 and 3C454.3, seem to contain extended steep spectrum components which dominate the spectrum at long wavelengths. We shall return to this point later.

Table 1 Summary of references used

Source names	Optical properties	Infrared flux	Radio flux	Radio polarisation
0048-09 OB-080	7		8-10*	*
0300+47 4C47.08	11	1, 12-15	11*	11*
OE 400				
0851+20 OJ287	1, 12, 16, 13, 17-20		10, 12, 16, 13, 21-23*	12*
0912+29	24		24, 25*	*
1101+38	26		26*	*
1215+30 ON 325	1, 27	14	25*	*
1219+28 W Coma	1, 27	14	28, 25*	*
ON 231				
1514-24 AP Lib	1, 29, 30	14	31, 32, 33*	*
1727+50 IZW -187	34, 35, 2		2*	*
2200+42 BL Lac	13, 1, 36-44	14, 13, 40, 45	14, 21, 46-50*	46, 49*

*, Our measurements.

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The four variable BL Lac type objects are among the most violently variable source in our programme in terms of both the amplitude and the time scale of the outbursts. We have attempted to assign a characteristic time scale to the larger variations for these and for the 21 other variable sources. The distribution of time scales is shown as a histogram in Fig. 3. It should be noted that this is necessarily a rather subjective procedure. Our observations were spaced at intervals of four to six weeks, so we cannot resolve time scales shorter than this. Most variable sources exhibit a range of time scales, and indeed OJ287 and BL Lac show small amplitude variations on a time scale of less than a day^{12,13}. Also there are certainly objects other than BL Lac type objects which vary on a time scale of less than three months.

In Table 2, we compare the relative amplitude of the outbursts for the four BL Lac type objects and the 21 other variable sources. This is computed as $(S_{\max} - S_{\min})/S_{\text{average}}$, where S is the flux density. Median values of this quantity are given at both wavelengths for the two groups. These 21 radio sources include all those extragalactic radio sources known to be variable as of January 1972, and include such well known sources as 3C120 and 3C454.2. Again, although as a group the variable BL Lac type objects exhibit the most extreme behaviour, examples of other sources can be found which show just as large amplitude variations.

Linear polarisation

The linear polarisation of the four BL Lac type objects also shows important differences from the other sources. First, we note that for all sources changes in polarisation can be considerably more rapid and larger in amplitude than the changes in flux density.

It is often illuminating to represent a polarised flux density P with a position angle χ as a vector $P \exp(2j\chi)$ in the argand diagram. This is identical to plotting the Stokes parameters U against Q . Although the time behaviour of the polarisation becomes more difficult to follow, the advantage is that any constant contribution to the observed polarisation from non-variable components in the source is simply represented as a constant displacement in the diagram.

When this is done, a striking difference between the BL Lac type objects and the other sources is apparent. In Fig. 4 an example of each type of behaviour is shown.

The data for 0048-09 cover all four quadrants of the diagram. 1055+01 also shows large variations, but the data are well displaced from the origin and are contained in a cone subtending less than 90° from the origin. We have measured the angle of this "cone", $\Delta\phi$, and the results are shown in Fig. 5.

It is interesting that the only source that shows variations in position angle at both wavelengths as large as those of the BL Lac type objects is 0607-15, which has been identified⁵² simply as a "stellar object". It is also one of the more rapidly varying sources ($\tau \sim 5$ months), and it is possible that when optical spectra are taken, it may also turn out to be a BL Lac type object.

The centroid of the region covered by data points in these vector diagrams is an estimate of a constant or slowly changing component of the total polarisation; excursions from this centroid represent the polarisation of individual outbursts. The preceding results then indicate two things. First, for the BL Lac type objects at least, the polarisation of different outbursts has differing position angles, implying differing magnetic field orientations. Secondly, any constant contribution to the polarisation is quite small for the BL Lac type objects but comparatively large for the other sources.

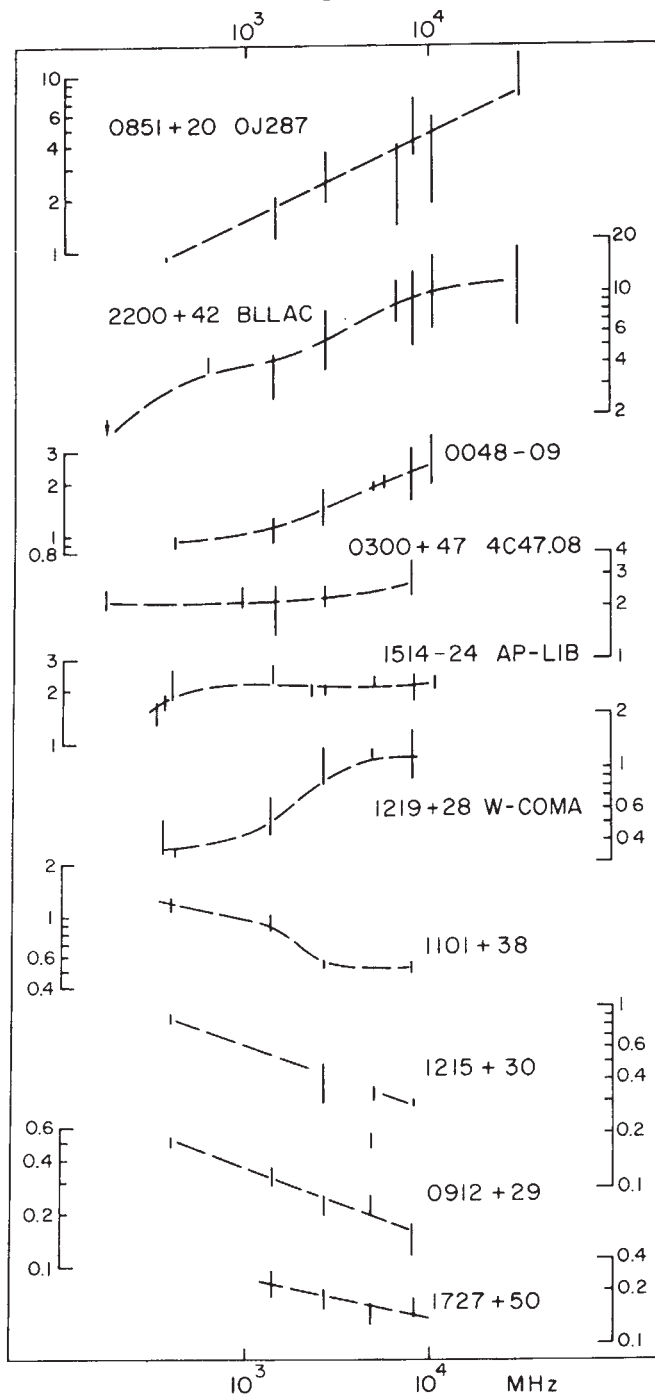
The effect is shown in another way in Fig. 6, in terms of the "average" polarisation at λ 11.1 cm. The "average" here is simply a vector average of all the observations for each source. Again, the average polarisation of the BL Lac type objects is small, although individual data points may have a much higher polarisation, and non-BL Lac type sources tend to have a much more strongly polarised constant component.

This result together with the large percentage amplitude variations and the absence of steep spectrum components visible at long wavelengths suggest that these four BL Lac type objects are extremely young objects which have yet to develop extended non-variable optically thin structures surrounding them. It is interesting that the only BL Lac type object known to have extended radio structure on the scale of seconds of arc is AP Lib (ref. 53), which does not show a strong centimetre excess, shows little evidence of variability, and has an average polarisation at λ 11.1 cm of 5.4%.

Distances

There has been some controversy concerning the distances to the BL Lac type objects. Stein *et al.*⁴⁵ and Visnavathan²⁰ derived distances to BL Lac and OJ287 of less than 1 Mpc by using indirect arguments based on the radio and optical variability.

Fig. 1 Radio spectra of ten BL Lac type objects. The data are taken from the references in Table 1. The error bars include the known range of variation. No effort was made to take into account differing absolute calibrations.



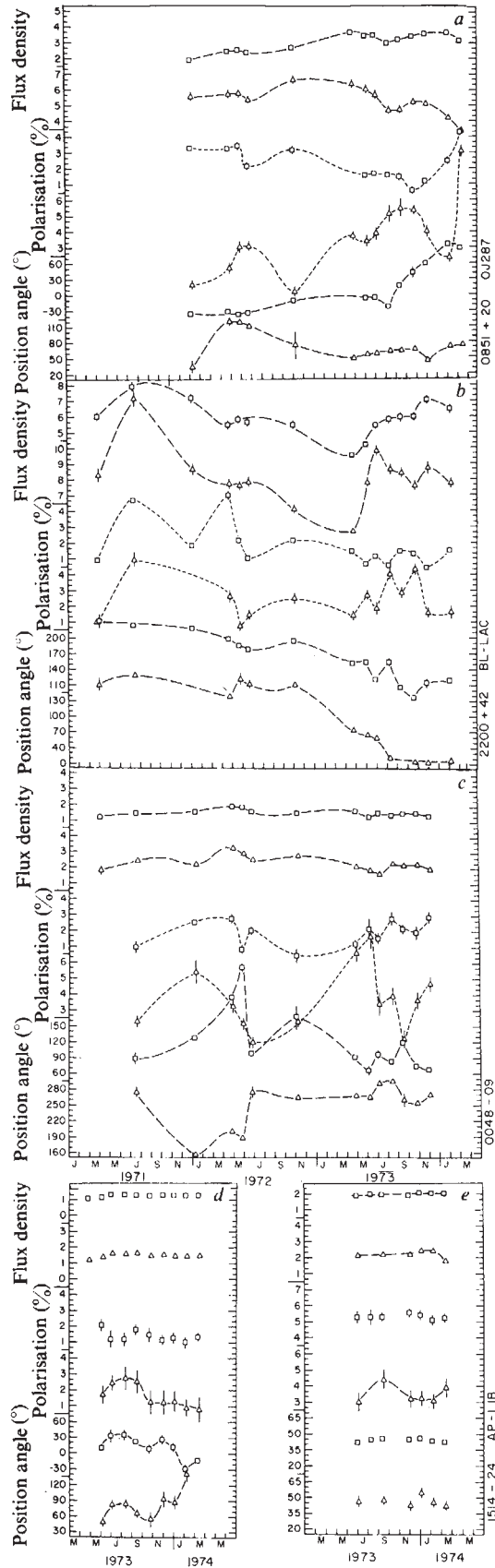


Fig. 2 The data for five BL Lac type objects. The points represent the flux density (Jy), percentage linear polarisation, and position angle (degrees), at $\lambda = 11.1$ cm ($\square$) and $\lambda = 3.7$ cm ($\triangle$). The lines connecting the data points were drawn by hand simply as an aid to the eye.

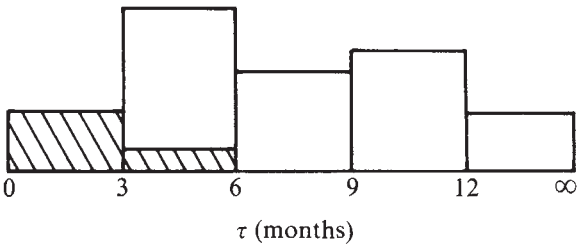


Fig. 3 Distribution of time scales for 25 variable sources. $\blacksquare$, BL Lac type.

lity data. But Oke and Gunn³⁶ have measured a redshift of 0.07 for the optical nebosity surrounding BL Lac, implying a distance of some 350 Mpc if the redshift is cosmological. We shall discuss briefly the method used by Stein *et al.* and by Visnavathan, since similar arguments have also been used to show that some variable quasars must also be at very small distances (see ref. 54).

The method is based on two physical arguments. First, the time scale of the variations should be less than the light travel time across the source ($r < c\tau$) where r is the radius of the emitting region. Secondly, if catastrophic inverse Compton losses are to be avoided, the energy density of the magnetic field must exceed the energy density of the photons ($B^2/8\pi > 3L/4\pi r^2c$), where B is the magnetic field and L is the total luminosity of the source. Combining these, an upper limit to the distance of the source can be written roughly as

$$D < 6100 \left[\frac{B}{1 \text{ gauss}} \right] \left[\frac{c\tau}{1 \text{ light yr}} \right] \left[\frac{\Delta s}{1 \text{ Jy}} \right]^{-1/2} \left[\frac{\nu_c}{10^{11} \text{ Hz}} \right]^{-1/2} \text{Mpc} \quad (1)$$

where Δs is the amplitude of the outburst, and ν_c is an upper cutoff to the spectrum of the outburst.

If the source is expanding relativistically with a Lorentz factor γ , then this limit may be increased by a factor $\gamma^{7/5}$. This is probably not very important compared with the other uncertainties in evaluating equation (1).

Table 2 Amplitude of the flux variations		
	BL Lac type	21 other sources
$\lambda 11.1$ cm	55%	25%
$\lambda 3.7$ cm	70%	40%

There has been some confusion as to the appropriate values to insert in equation (1). We stress that these quantities refer only to the outburst, and not to the source as a whole. Also, it is often implicitly assumed that the source is a uniform homogeneous region. There is considerable evidence against this: (1) the optical and radio outbursts seem to be uncorrelated; (2) the polarisation at optical wavelengths is usually very much higher than that at even the shortest radio wavelengths¹²; (3) the radio spectrum rarely shows a spectral index as steep as -2.5 ; (4) the uniform expanding cloud model of Van der Laan⁵⁵ rarely fits the data²¹; (5) VLB observations reveal extremely complex structure on the smallest scales⁵⁶.

In view of this, it may be dangerous to derive magnetic field strengths from the usual synchrotron self-absorption argument. It is almost certainly wrong to apply a value of the field derived from radio data to the optical region, or a value of the time scale taken from the optical variations to the radio region.

Sometimes the magnetic field strength in the optical region

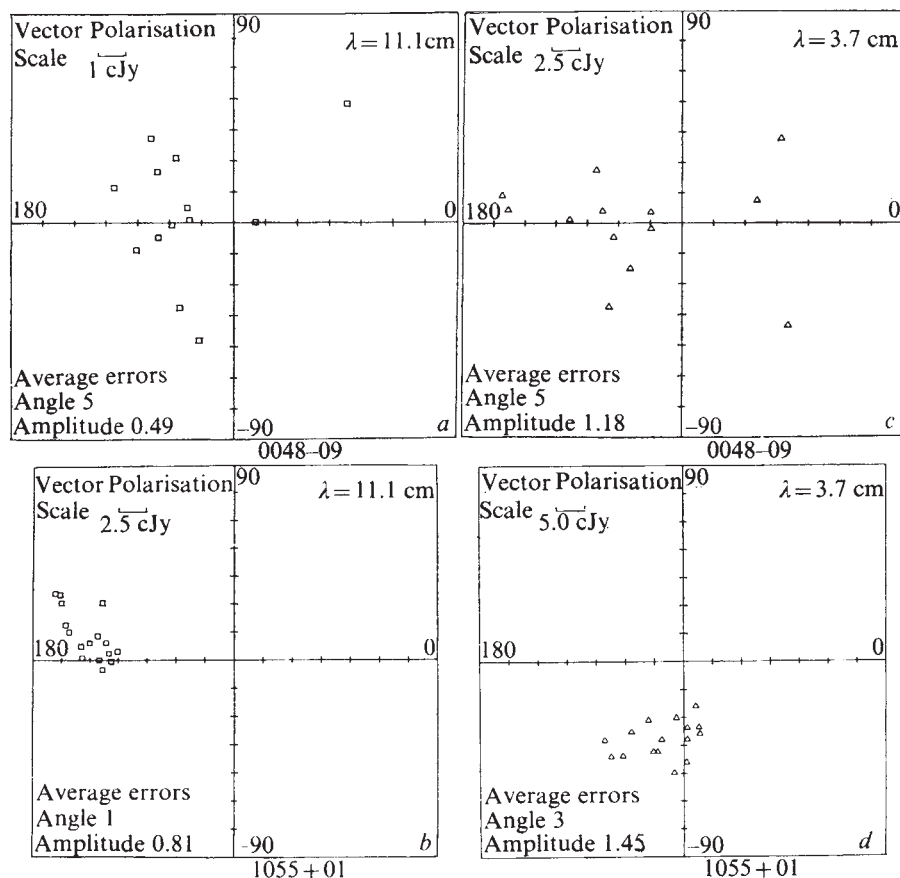


Fig. 4 The data for 0048-09 (BL Lac type) (a, c) and 1055+01 (non-BL Lac type) (b, d) plotted on the argand diagram.

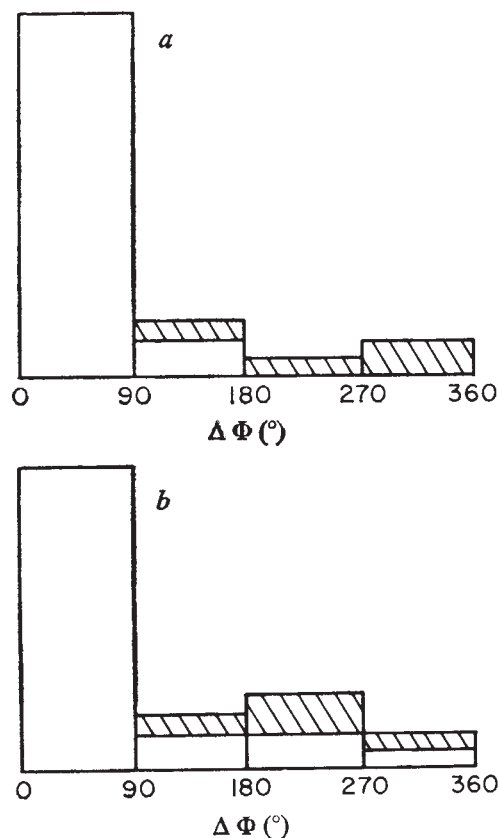
is estimated from the requirements that the half life of the electrons against synchrotron losses be greater than the time scale of the burst. But Peterson and Dent⁵⁷ have given evidence that continuing injection of electrons takes place over comparatively long time scales in at least some radio outbursts. It is possible that the rapid fluctuations seen at optical wavelengths represent fluctuations in the injection rate for relativistic electrons rather than the development of an expanding cloud. Although this increases the energy requirements, we know so little about the source of the energy that this is hardly a strong objection.

If we insert typical values into equation (1), ($B \sim 0.1$ – 10 gauss, $\tau \sim 0.1$ – 0.3 yr, $\Delta s \sim 1$ – 10 Jy, $\nu_c \sim 10^{11}$ – 10^{15} Hz), we obtain a range of distances from 200 kpc to 2,000 Mpc. In view of the uncertainties discussed above, and of the lack of a detailed physical understanding of these sources, we feel it is unwise to try and be much more specific. This estimate certainly allows the BL Lac type objects to be extragalactic objects at great distances, and is entirely consistent with the redshift of 0.07 found for the optical nebula surrounding BL Lac. Finally, a source with a diameter of 0.3 light yr at a distance of 100 to 1,000 Mpc would have an angular diameter in the range of 0.2×10^{-3} – 2×10^{-3} arc s. This is consistent with VLB observations^{56,58}. Jones *et al.*⁵⁹ have recently presented a more comprehensive account of the distance problem.

General nature of BL Lac type objects

If BL Lac type objects are defined solely by a very small optical line-continuum ratio, then as we have shown, they form a very nonhomogeneous group in their radio properties. In fact they show the whole range of properties exhibited by other compact extragalactic radio sources. Some of these objects have comparatively steep spectra and appear not to be variable, while others show a centimetre excess and are certainly highly variable. The three sources BL Lac, OJ287 and 0048-09 are among the most rapid and violently variable radio sources known, and seem to represent an extreme of the

Fig. 5 Distribution of the angle $\Delta\Phi$ for 25 variable sources. a, $\lambda = 11.1$ cm; b, $\lambda = 3.7$ cm; ■, BL Lac type.



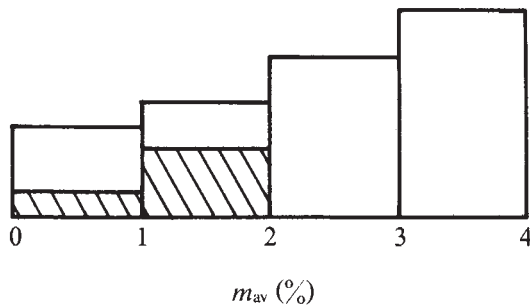


Fig. 6 Distribution of the mean polarisation at $\lambda = 11.1$ cm for 25 variable sources. $\lambda = 11.1$ cm; ■, BL Lac type.

variable radio source phenomenon. All the evidence is consistent with their being extragalactic objects at great distances. They may be among the most luminous objects in the Universe.

For the most variable BL Lac type objects, the spectrum, flux variations, and polarisation data all suggest strongly that they are extremely young sources which have not yet developed extended non-variable optically thin radio structure surrounding them. In this respect they may be pictured as "naked" radio sources.

This view is consistent with the results of Condon and Jauncey⁶⁰ who give evidence that BL Lac type objects may have been ejected recently at high velocity from nearby galaxies. It is perhaps tempting to label these sources as "streakers".

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letters to nature

Radio brightness distribution of 3C273

THE radio source 3C273 was one of the first to be identified with a QSO. The main features of the brightness distribution have been established from lunar occultation studies²⁻⁵, which show that the source is double, with one component coincident with a 13 mag QSO or redshift 0.158. This component, 3C273B, is variable, and has an inverted radio spectrum. The component is compact, and details of its structure have been investigated with inter-continental (VLBI) interferometers⁶⁻⁸. The other component, 3C273A, has a normal radio spectrum and is identified with a faint optical jet lying in position angle 223° with respect to the QSO. Component A has extended radio structure, and is not detected in VLBI observations⁹. The colours of the jet indicate that the optical emission, like the radio emission from component A, is non-thermal^{9,10}. The optical jet of 3C273 is an extremely unusual feature, and it would be interesting to make a detailed comparison of the optical and radio

structure associated with the component. We provide here detailed information of the radio brightness distribution.

The source has not been mapped by aperture synthesis techniques because of its proximity to the celestial equator (declination +2° 20'), which severely restricts the resolution available in declination for instruments with E-W baselines. Lunar occultations of the source are of short duration, and the details of the brightness distribution obtained by this method are consequently limited by poor signal-to-noise ratio. In a previous study¹¹, we used interferometer observations to obtain strip brightness distributions along the major axis of 3C273 with a resolution of 7", but were not able to resolve the structure perpendicular to this axis.

We have now assembled observations of 3C273 made by ourselves and others using radio-linked interferometers based on Jodrell Bank. The outstation telescopes were situated at Wardle, Defford and Pocklington, which are respectively 23 km, 127 km and 132 km from Jodrell Bank. The observations were made at various wavelengths between 18 and

74 cm (frequencies 1,666–408 MHz), giving effectively eight different tracking interferometers with projected spacings up to about $150\text{ k}\lambda$. The maximum resolution available is of the order $1.5''$. A plot of the coverage of projected spacing (u, v) is shown in Fig. 1.

The double structure of 3C273 appears in the interferometer observations as a pattern of repeated maxima and minima in the fringe amplitude across the u - v plane. If components A and B were both unresolved, the loci of maxima and minima would be parallel straight lines. In fact, the observations show that the loci depart from this behaviour in a systematic way. Furthermore, the values of the maximum and minimum fringe amplitude also change systematically across the u - v plane. The data show that one component is unresolved at these spacings, and that the

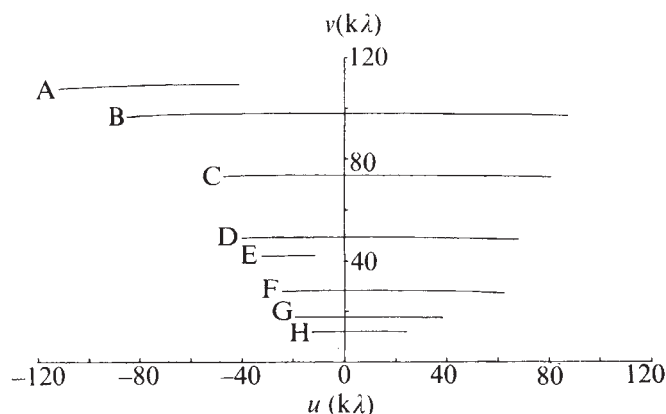


Fig. 1 The projected interferometer spacings on the resolution (u - v) plane. The observations A and B were made at $\lambda 74\text{ cm}$ using the Jodrell-Malvern and Wardle-Malvern interferometers respectively. Observations C are from the published data of Anderson and Donaldson at $\lambda 74\text{ cm}$ (ref. 15). The observations D to H were made with the Jodrell-Wardle interferometer at $\lambda 18, 21, 31, 49$ and 74 cm respectively.

variations are entirely due to the resolution of the second component. The flux density of the unresolved component agrees with the flux density of component B derived from lunar occultation studies¹². We therefore use component B as a phase reference source, and by noting the amplitude and exact position of each maximum and minimum, we have deduced the amplitude and phase contributed by component A alone.

To combine the observations at different wavelengths, we have normalised the fringe amplitudes of component A by dividing them by the flux density of A obtained from lunar occultation data¹². The values of normalised visibility vary smoothly across the u - v plane in a manner that depends solely on resolution and not on observing wavelength. We conclude that the structure of component A is independent of wavelength over the range 18–74 cm. This is consistent with our previous study at lower resolution¹¹.

We have performed a two-dimensional Fourier transform of the visibility data derived from all the baselines to produce a synthesis map of the brightness distribution of component A. The map has been treated by the CLEAN procedure¹³ to reduce the unwanted sidelobe responses caused by the incomplete coverage of the u - v plane. The resulting 'cleaned' map is shown in Fig. 2, together with a representation of the restoring beam, which has a half power width of $1.5''$. A small region of negative brightness to the south of the main peak is a remnant of the main negative sidelobe produced by the original Fourier transformation, and indicates the confidence level of the map. Errors

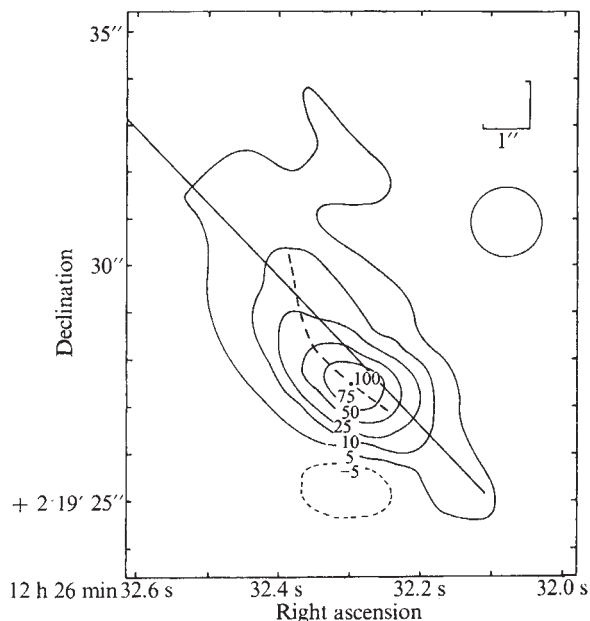


Fig. 2 The radio brightness distribution of 3C273A. The contour levels are expressed as percentages of the highest brightness. The ridge of peak radio brightness is represented by the curving dashed line. The solid line in p.a. 223° is a schematic representation of the optical jet (tip at lower right). Component B (the QSO) lies on the extrapolation of this line to the left, $25''$ from the tip of the optical jet. Circle denotes beam used.

resulting from noise and confusion are much less than the lowest contour interval.

Schmidt⁹ originally described the optical jet as a faint wisp which has a width of 1 – $2''$ and extends away from the QSO in p.a. 223° . The optical brightness distribution along the jet has been measured photoelectrically¹⁰; the feature is first detected about $10''$ from the QSO and fades into the noise at a distance of about $25''$. There is no obvious peak in the optical brightness.

The radio brightness distribution of component A shows a pronounced peak of emission approximately $0.5''$ south of the axis of the jet. The peak may contain unresolved structure. We believe that the uncertainty in the optical position is such that the radio peak could in fact coincide with the axis of the jet. There is an extended region of radio emission at the inner or North following end of component A. Although the surface brightness of the emission is low, the integrated flux from this region as a whole is appreciable. There may also be a low brightness extension to the outer, South preceding, tip of the component. The integrated flux density of this extension is low, however, and the reality of the outer feature is not firmly established.

We show the ridge line of maximum radio brightness as a dashed line in Fig. 2. The extended region at the inner end of component A is clearly displaced to the north of the nominal axis of the optical jet. The angular displacement is 1 – $2''$, which corresponds to a linear displacement of 3 – 7 kpc if 3C273 lies at the cosmological distance suggested by its redshift. The displacement would be even more marked if the radio peak actually lies on the axis of the optical jet. We emphasise that this skewness in the brightness distribution of component A is not produced as an artefact of our analysis procedure, but is a real feature which may be detected in the original interferometer data.

Harris¹⁴ has noted a number of double radio sources in which the components show non-aligned structure. It seems that 3C273 can be included in this category. Harris discusses some possible interpretations of this phenomenon. In the case of 3C273, however, the alignment of the optical jet

makes the problem of explaining the non-alignment of the radio component even more severe.

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Comparison of sunspot periods with planetary synodic period resonances

For decades, the closeness of the 11.1-yr cycle of solar activity and the 11.86-yr period of Jupiter has been noted, along with some speculation that the planets may have a causal effect on triggering solar activity. Two studies^{1,2} have presented a planetary function which stays in phase for hundreds of years, and both of them considered the influence of the planets with large values of mass/(distance to Sun)³ or (m_i/d_i^3) , namely Jupiter, Venus, Earth, and Mercury, although Mercury effects were not evaluated quantitatively in either case because of the assumption that they would represent a short term perturbation. Okal and Anderson³ indicate that Mercury effects can be important and that the magnitude of the tides of the Sun do not have the same power spectrum as the solar activity.

Table 1 Dependence of planet synodic period beat period on synodic period variation. Top row and left column based on data from 1930–60. A 0.1% change in a synodic period changes the beat period by about 5%

	$T_{EJ} =$ 1.0909 yr Low	$T_{EJ} =$ 1.0921 yr Mean	$T_{EJ} =$ 1.0932 yr High
$T_{EV} =$ 1.5970 yr Low	22.14 yr	21.19 yr	20.40 yr
$T_{EV} =$ 1.5987 yr Mean	23.16 yr	22.13 yr	21.26 yr
$T_{EV} =$ 1.6007 yr High	24.49 yr	23.34 yr	22.38 yr

Although this paper does not consider Mercury, it presents a more general model than just a tidal concept; tides are likely to be less important than torque effects on the oblate spinning Sun, for example. The study reported in ref. 3 was limited to an evaluation of the maximum tidal potential. Lack of correlation of this function with solar activity is not equivalent to reducing the credibility of all planetary hypotheses of solar activity.

To determine the possible influence of several planets simultaneously on the Sun, it is convenient to consider them two at a time, as reflected by the synodic periods (periods between successive conjunctions). For zero eccentricity orbits, the (m_i/d_i^3) effects are exactly the same at conjunction as at opposition, and therefore one-half the synodic period is the repetitive reinforcement period. This is shown clearly in Fig. 1, which represents by a cosine function a forcing function of periods $T_{ij}/2$. In the figure, the ordinates are the cosine of twice the angle between planets i and j , and the function is shown at 0 yr, near 11 yr, and near 22 yr, assuming that at time $t = 0$, $\theta_E = \theta_V = \theta_J = 0$. Twice the angle is consistent with a (m_i/d_i^3) term physically associable either with tidal effects or with torque effects on the oblate spinning Sun. With all functions starting at a maximum, after 0.8 yr two are almost exactly out of phase and after 1.6 yr all are almost exactly in phase again, except for a time delay Δt . Considering now the EV and EJ curves, after enough (say n) 1.6-yr cycles, the accumulated Δt will be equal to one $T_{EJ}/2$ time interval. If we

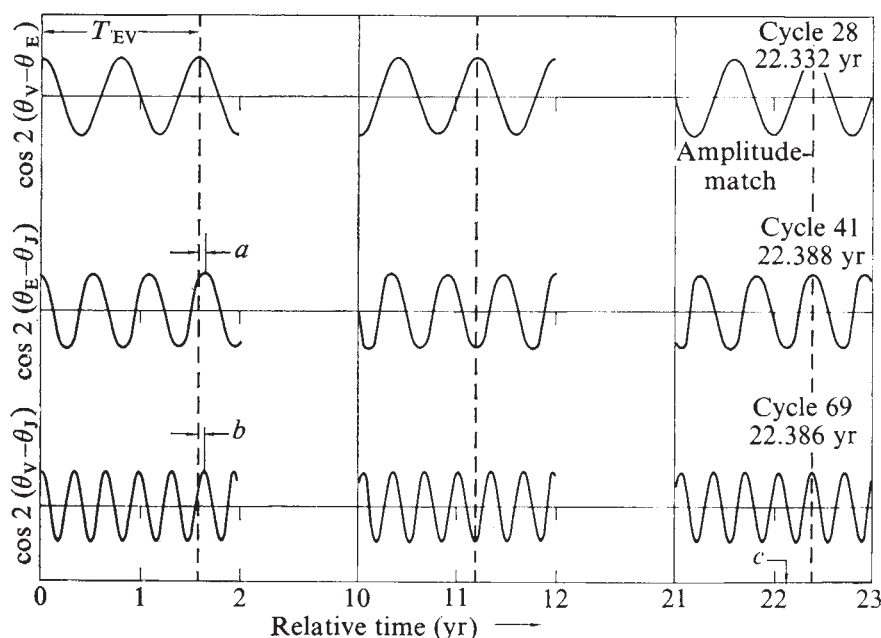


Fig. 1 Synodic angle cosine functions of planets for (m_i/d_i^3) effects: Earth–Venus (EV); Earth–Jupiter (EJ); and Venus–Jupiter (VJ), respectively. θ is measured with respect to an inertial reference such as the first point of Aries. Although the magnitudes match at 22.38+ yr, the nominal phase match occurs near 22.14 yr by equation 4. As seen from equation 6, this is conceptually equivalent to a simple harmonic of the difference frequencies of the EV and EJ curves. At 22.38+ yr in this zero-eccentricity model the planets and Sun would be lined up to within $\pm 0.5^\circ$, but 139° from the starting line-up. At 22.14 yr, the planets, Sun, and original line-up at $t = 0$ are within $\pm 48^\circ$, and at 11.07 yr, within $\pm 24^\circ$. a , $\Delta t = \frac{1}{2}(T_{EJ} - T_{VE})$; b , $\Delta t = \frac{1}{2}(T_{VJ} - T_{VE})$; c , phase match, equation (4), 22.135 yr.

assume that the time required for this phase shift of one $T_{EJ}/2$ cycle to yield a synodic period resonance is equal to the period of the 22-yr solar cycle T_S , then for $n T_{EV}$ periods

$$T_S = n T_{EV} \quad (1)$$

If the mismatch is $T_{EJ}/2$, then

$$n = (T_{EJ}/2 \Delta t) \quad (2)$$

and

$$\Delta t = (3T_{EJ}/2) - T_{EV} \quad (3)$$

from Fig. 1. Since $T_{EV} = T_V T_E / (T_E - T_V)$ and $T_{EJ} = T_E T_J / (T_J - T_E)$ for circular orbits, then from equations (1), (2), and (3)

$$1/T_S = (3/T_V) - (5/T_E) + (2/T_J) \quad (4)$$

The same result is obtained using $n = (T_{VJ}/2)/\Delta t$ and $\Delta t = (5T_{VJ}/2) - T_{VE}$; or alternatively using $T_S = 3nT_{EJ}/2$, $n = T_{VJ}/3 \Delta t$ and $\Delta t = (3T_{EJ}/2) - (5T_{VJ}/2)$, using the same logic to find resonances.

Using $T_V = 0.6152104$ yr
 $T_E = 1.0000388$ yr
 and $T_J = 11.862238$ yr in equation (4)

we obtain $T_S = 22.1353$ yr
 and $T_S/2 = 11.0676$ yr (5)

Notice on Fig. 1 that at about 11 yr there would have also been an alignment of minima in the two lower curves, corresponding to a one-half cycle phase shift in contrast to a full cycle phase shift at about 22 yr.

Since expression (4) can also be written as

$$(1/T_S) = (3/T_{EV}) - (2/T_{EJ}) \quad (6)$$

the variation of the synodic periods due to eccentricity can have a large influence on the computed value of T_S . The mean synodic period over a large number of 11+ yr periods and its variability was determined by the examination of computer-generated conjunction-opposition data from 1930 to 1960.

$T_{EV} = 1.6007$ yr high
 $= 1.5987$ yr mean (20 samples) (1.59872 yr theoretical,
 zero eccentricity)
 $= 1.5970$ yr low
 and
 $T_{EJ} = 1.0932$ yr high
 $= 1.0921$ yr mean (40 samples) (1.09211 yr theoretical,
 zero eccentricity)
 $= 1.0909$ yr low

The influence of the variation of T_{EV} and T_{EJ} on T_S in equation 6 is shown in Table 1. A small change in planetary synodic period can lead to large changes in the value of T_S . For example, the nine values of Table 1 have a mean of 22.28 and a standard deviation of ± 1.2 , to be compared with the mean and standard deviation of the real 22-yr cycle as follows:

$T_S = 22.35 \pm 1.76$ yr (minima, preceding odd cycles)
 $T_S = 22.23 \pm 2.09$ yr (minima, preceding even cycles)
 $T_S = 22.13 \pm 2.47$ yr (maxima, even cycles)
 $T_S = 22.13 \pm 2.93$ yr (maxima, odd cycles)

Preceding sunspot data were taken from Waldmeier⁴ using data from 1610.8 to 1957.9. The values of Table 1 are based on a 30-yr interval only instead of the 350-yr sunspot data base. Also, the values of T_{EJ} and T_{EV} are correlated because motion of the Earth at perihelion, for example, would have a tendency

to reduce T_{EJ} and increase T_{EV} . This would have the effect of further increasing the expected resonance period variations from the zero eccentricity value of 22.135 yr, and can be inferred from Table 1.

This work shows not only a good correlation between planetary synodic period resonances with solar activity period, but also a rough correlation between the variations of the resonance period resulting from orbit eccentricity and the variations of the sunspot period. These correlations could be considered as a motivation for reassessing the physical mechanisms and attendant energy production magnitudes associated with all (m_i/d_i^3) effects of the planets on the Sun in addition to the tidal effects considered in refs 2 and 3.

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Radio wave propagation and ionisation of meteoric constituents

WE have studied from Calcutta (22°34'N; 88°24'E) the effect of meteoric ionisation on radio wave propagation characteristics in the low frequency band, where most radio aids for aerial and marine navigation operate. For the past few years we have been recording during the daytime the field strength of a radio navigational signal on 280 kHz (call sign JR) transmitted from Jessore (23°10'N; 89°10'E), about 110 km from Calcutta. Preliminary results indicated that meteors can produce significant ionisation below the ionospheric regions around 85 km responsible for the reflection of the low frequency signal, causing sizeable radio absorption events during major meteor shower activities^{1,2}. Here we present new results obtained from a detailed analysis of the data for the periods of major meteor showers during a one year period from June 1972 to May 1973, which indicate that the dissipation of the ionised trail produced along the path of a meteor depends on the ionic characteristic of the trail.

The receiver used is basically a low noise superheterodyne receiver with bandwidth 2 kHz and gain 120 dB; the aerial used is of the inverted L type with vertical and horizontal parts 10 m and 50 m long, respectively. The effective height and the terminal capacitance of the aerial are respectively 9.17 m and 304 pF. The aerial is connected to the receiver input through a small capacitor (1 pF) to reduce the coupling of the antenna to the receiver. For a vertically polarised radio wave travelling horizontally towards the antenna, the vertical part of the inverted L-type antenna picks up the signal, while the horizontal part effectively improves the current distribution in the vertical part and effectively increases the signal pickup. If, however, the signal contains a horizontal component of polarisation, as may be expected for the sky wave, the horizontal part of the antenna will pick it up and add vectorially to the voltage picked up by the vertical part. The longer horizontal part of our inverted L antenna aligned in the direction of transmission picks up the horizontal component of the sky wave, which is larger than the vertical component because of the geometry of the ray path involved. Further, the antenna launching factors (F_T and F_R , T and R referring to the transmitter and receiver respectively) will in the case of poor ground conductivity reduce the ground-wave field significantly, while the sky wave component for the propagation distance involved is practically unaffected. In fact, the ground conductivity in the receiving location, which is situated in the heart of Calcutta, is extremely poor, being

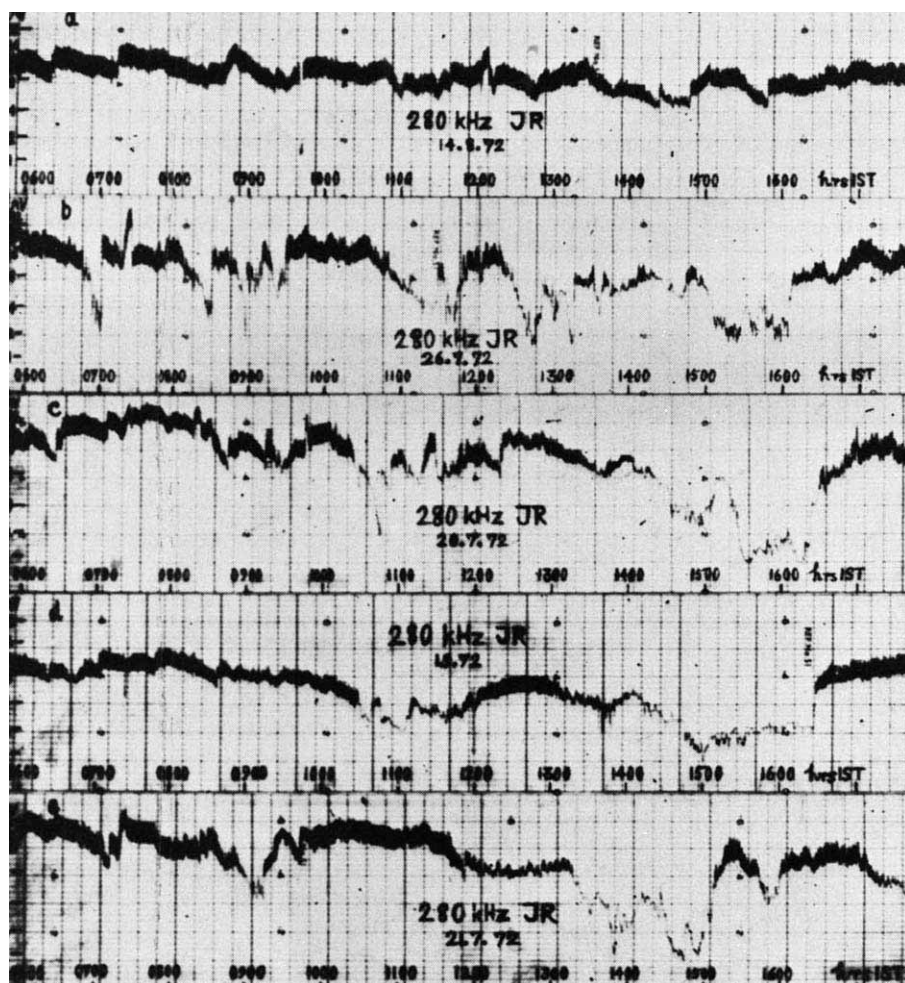


Fig. 1 Photograph of typical records showing the effect of meteor ionisation on the field strength of the low frequency signal. The ordinate shows the receiver input $(\mu V)^{1/2}$.

about 10^{-4} – 10^{-5} times that of seawater. In addition since the transmission frequency is 280 kHz, which is much less than the gyrofrequency of 1.2 MHz involved, and the plane of propagation is inclined to the magnetic meridian at a large angle of about 45° , the presence of the Earth's magnetic field would reduce the absorption of the sky wave significantly³. The combined effect of these propagational factors make the sky wave-ground wave ratio significant so that the measured field shows up ionosphere changes.

The absorption process involved in the present case is predominantly collisional and the phase height remains fairly constant. Therefore, phase changes of sky wave at such times could be ignored.

Some of the typical records showing the effect of meteor ionisation on the field strength of the low frequency signal involved are reproduced in Fig. 1. Figure 1a shows a sawtooth type of fade out (SF) pattern in the form of a gradual fall of field strength starting successively at about 0600, 0623 and 0715 IST followed by sudden rises occurring at about 0620, 0714 and 0840. A similar effect is also noticeable in Fig. 1b, c starting at about 0600 and 1005. Each of these effects was, however, accompanied by an opposite effect appearing in the form of a gradual rise followed by a sudden fall. The opposite effects started (Fig. 1b and c) at about 0715 and 1115. In addition Fig. 1b, c, d, e shows a remarkable trapezoidal fade out (TF) pattern starting at about 1410, 1400, 1405 and 1150. In all these cases, the fall is again gradual whereas the rise is fast with a significant time elapsing between fall and rise. The absorption events occurred both during day and night. The results of a detailed analysis of the daytime records of the SF effects observed during the periods of the meteor showers for the one year period under consideration are presented in Fig. 2.

During this period there were 474 distinct SF effects, presumably associated with major meteor shower activities. Figure 2 shows the ratio of the time of gradual fall of field strength, t_f , to the time of sudden rise, t_r , as plotted against the time of gradual fall, normalised by dividing both the parameters by the total duration, t_d . The total duration, t_d , is just $(t_f + t_r)$ for the SF effects and is of the order of 30 min; visual meteors usually last only for a few tens of seconds. The ionisation in meteor trails, which affects the LF propagation, lasts for a significantly longer time, resulting in the observed absorption event. From Fig. 2 it is clear that there is a tendency for data points to lie on several distinct straight lines with a remarkably low scatter up to at least the seventh line from the top. The slope of the lines seems to decrease gradually from the top to the bottom. The scatter of the data points increases below the seventh line and no clear linear relationship is observable for very low values of $(t_f/t_r)/t_d$. We attempted to explore the nature of variation of data points for the period of an individual meteor shower. For this, the data collected during the period of detectable dates of meteors for different showers for the 1-yr period were plotted separately, and it was found that even for a given shower period they seem to lie on the same distinct straight lines with different slopes.

The ionospheric regions responsible for the reflection of the l.f. signal involved are near the "meteor height". But the height of maximum meteor ionisation depends on velocity and mass of a meteor, being higher for greater velocities and lower masses. The ionisation produced by meteors of different masses and with different velocities would, therefore, affect the propagation of the signal in different ways. When the ionised trail is formed at the absorption level of the low frequency signal involved, the signal is absorbed. Whether the effect

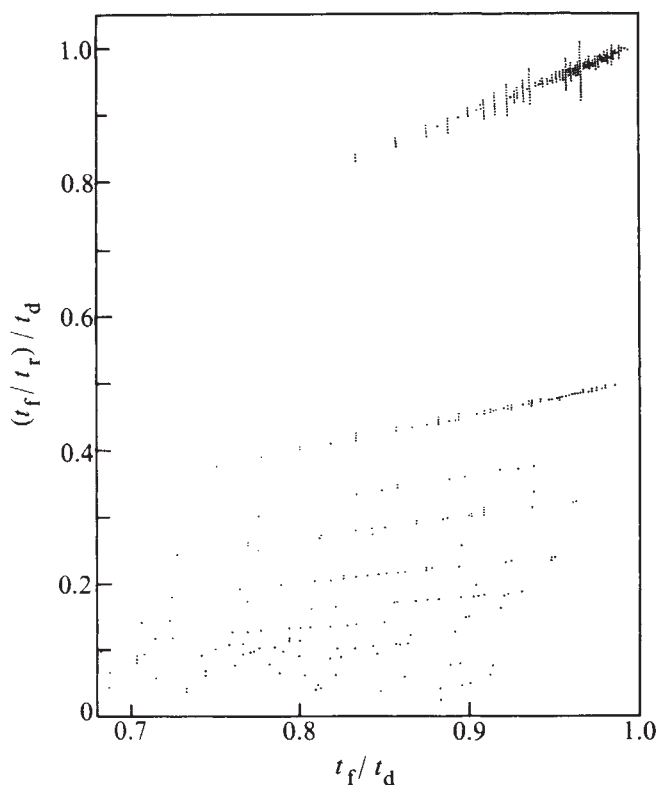
appears as SF or TF is determined by the electron line density in the trail and it is believed that the SFs and TFs are the same type of effect but that in TFs the ionisation in the absorption regions is much larger causing the signal to be drowned in the background of noise plus ground wave. It has been found that a TF effect would occur from an ionised meteor trail having an electron line density one order of magnitude greater than that in a trail causing a typical SF absorption event. The opposite type of SF effect is likely to be produced by a similar meteor trail ionisation at the low frequency reflection level involved. The duration of the absorption events is governed by the lifetime of the meteor trail ionisation, which, in turn, depends on the way the trail dissipates. There are several factors such as diffusion, recombination, attachment, turbulence and wind shears which contribute to the dissipation of the ionised trail. Of these, ambipolar diffusion is the most important factor for the eventual dissipation of the meteor trail ionisation. By diffusion the ionised trail expands at a relatively low rate producing a radial distribution of electrons which assumes a Gaussian distribution. If r_e is the radius of the expanded trail when the volume density in the trail is N_e , the critical volume density for the wavelength involved, then the time variation of the absorption of the signal would be expected to follow the variation of r_e with time. From a knowledge of the critical radius r_e the duration of the absorption event could be estimated, and it has been found that it depends markedly on λ , the wavelength involved. Hines and Forsyth⁴ show that the echo duration of v.h.f. scattered signal is proportional to the square of the wavelength. Since the wavelength involved in the present investigation is more than two orders of magnitude compared to that in a typical meteor radar observation in the v.h.f. band, the duration of the low frequency absorption event would be much longer. The duration also depends on the diffusion coefficient which, in turn, depends on height as well as the constituents of a meteor. Fourteen different materials

are common in meteors⁵. Of these, the atoms and ions that have been found in meteor spectra⁶ are: Al; Ca; Ca⁺; Co; Cr, Fe, Fe⁺, Mg, Mg⁺, Mn, Na, Ni, Si, Si⁺, Sr⁺. The relative abundances of different materials in a meteor may again vary from meteor to meteor. A wide variety of meteor spectra are observed in the optical and infrared ranges and Millman's⁷ classification of such a spectra indicates that the spectral class depends not only on the velocity of a meteor but also on the type of a particular meteor. Thus although the shower meteors with velocities in the range 30–50 km s⁻¹ are usually of type X, there are a few of type Y. Again, shower meteors with velocities from 20–30 km s⁻¹ may be of type X or Z. Even if the meteor compositions did not vary, the differences in velocities of individual meteor would alter the relative abundances of the ions available during ablation⁸. The distinctive abundances of ions in the trail, whether produced by the variation of meteorite composition or by differences in velocities of individual meteors would eventually control the diffusion rate in distinctive ways. It seems that the various lines shown in Fig. 2 may result from the meteor producing each ionised trail having a different ion as the most abundant constituent, because the ratio $(t_f/t_r)/t_d$ for a given value of t_f/t_d would depend on the diffusion coefficient D , which, in turn depends on the relative abundances of ions present in the trail. The uppermost line of Fig. 2 can be associated with the most abundant ion Fe⁺, which, being a heavy ion, would result in a high value of $(t_f/t_r)/t_d$, while the second, third, fourth and fifth lines from the top may be associated with Mg⁺, Ca⁺, Ni⁺ and Si⁺ as the most abundant ions respectively. The scatter of data points lying below the seventh line of Fig. 2 may result from other less abundant ions in the meteor trail. Besides these, the progressively lesser number of data points for lower lines is indicative of a smaller abundances of the constituent ions responsible for a particular line. We note that observations⁹ on the composition of meteors producing E_s ionisations in the night time ionosphere indicate that Fe⁺, Mg⁺, Ca⁺ and Ni⁺ are the main constituents of E_s ionisation, with decreasing orders of abundances. Further, the fact that the data points collected for the periods of different showers seem to lie on the same distinct straight lines indicates that the lines obtained result from the characteristics of the meteors, irrespective of the showers to which they belong.

The positive ions produced along the path of a meteor do not play any direct role in the ionospheric reflection of the radio signal but the relative abundances of the ions present in the trail controls the ambipolar diffusion of the trail, which is presumed to be the main cause of dissipation of the trail during absorption events.

The influence of meteor showers on low frequency propagation characteristics was also studied by Chilliers¹⁰ who observed that the shapes of the curves showing the hourly average speed of fading for three low frequency radio waves on 70 kHz, 113 kHz and 200 kHz were very similar. He compared the mean fading speed on 70 kHz with the mean number of meteors observed by radio methods and found a close association between the speed of the fast fading and the rate of incidence of meteors on the ionosphere. Earlier work by Weeks and Stuarts¹¹, on the measurement of the phase of waves near 100 kHz for short propagation path, showed that the diurnal phase curve was non-symmetrical, the morning decrease in phase height often exceeding the sunset increase. Chilliers thought this non-symmetry in phase height to be caused by discontinuous nocturnal changes in the height of reflection and attributed the phenomena to meteors. Some evidence of the effect of meteor showers on v.l.f. propagation characteristics came from the work of Chilton¹² who observed that the night-time phase height of 16 kHz transmissions for Rugby–Boulder propagation path remained unaltered during the period of meteor showers. Whenever the shower had passed or the entire path had become sunlit, the phase lag decreased rather abruptly to the normal daytime value, while on other days it decreased in a regular manner during sunrise.

Fig. 2 Scatter plot of the normalised ratios of the time of fall to that of rise of the SF effects against the normalised fall time.



The study of the low frequency radio absorption events during meteor showers, if supplemented by observation on v.h.f. forward scatter signals from the region of the lower ionosphere at the low frequency path mid-point may prove to be useful in revealing the true relationship between v.h.f. propagation and low frequency absorption resulting from meteor trail ionisation and may provide us with a deeper insight into the physical process involved.

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Laser depolarisation 'bright band' from melting snowflakes

LINEAR depolarisation ratios (δ) obtained with a continuous wave (CW) laser system demonstrate that melting snowflakes backscatter unexpectedly large amounts of depolarised energy. δ values derived from single-particle scattering interactions increase from ~ 0.5 (dry snowflake average) to ~ 0.7 for moderately melted snowflakes, providing evidence for the existence of a laser radar depolarisation 'bright band' analogous to that observed at microwave radar frequencies.

The ability to distinguish between spherical and aspherical scattering elements through remote sensing techniques is a consequence of the Mie theory which predicts that spherically symmetrical particles backscatter energy that retains the incident state of polarisation, whereas asymmetrical particles introduce a depolarised component into the returned energy. This principle has been used by microwave radar investigators for the discrimination of large raindrops and hailstones in convective storm clouds¹, and for the differentiation of water and ice particle clouds with laser radar (lidar)². Melting snowflakes have also been observed to produce microwave depolarisation³; regions containing precipitation a few hundred metres below the freezing level are often marked by a highly depolarised, intensely reflective layer (the bright band). This region contains large aggregates of ice crystals which have developed a liquid water covering (greatly enhancing the radar reflectivity compared with that of dry snowflakes), but which still fall at speeds slower than the more symmetrical, severely melted particles below. Because of differences in the modes of interaction of energies at the microwave and optical frequencies, it is not clear that a bright band analogy would be observed with lidar. If present, however, much

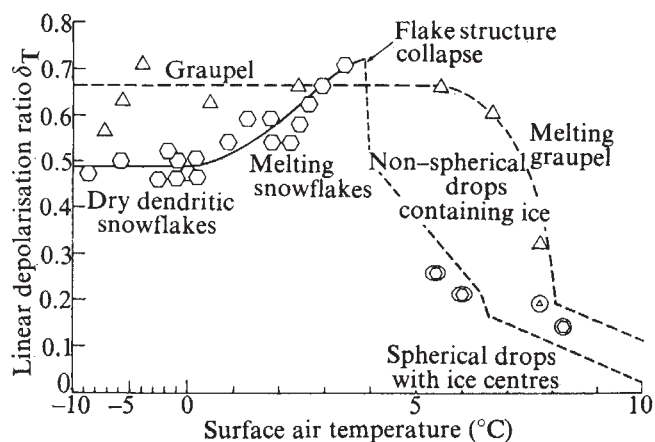


Fig. 1 Increase in depolarisation produced by melting snowflakes (hexagonal symbols) with increasing surface air temperature demonstrating the optical wavelength bright band analogy. Dashed lines represent the hypothesised backscattering behaviour of severely melted snowflakes and graupel particles (Δ) based on likely particle structural changes and geometric optics theory considerations, with data for non-spherical and spherical raindrops containing ice also shown.

useful information could be gained from studies of this feature (as demonstrated by the many related radar findings), while the characterisation of the return from melting precipitation could lead to a lessening of the confusion presently found in the lidar polarisation measurements reported from clouds.

An apparatus employing a vertically polarised CW helium-neon laser as a source has been designed to yield measurements applicable to those obtained by lidar to observe snowflake melting. Energy scattered in the backward direction from each particle falling through a small portion of the laser beam is collected by a receiver with a Glan-air polarising prism and dual photodetectors dividing the return into two components; the energy contained in the same plane of polarisation as that of the source, and that in the cross-polarised plane. The ratio of the orthogonal to parallel intensity components (δ , the linear depolarisation ratio) is measured by recording on film the scattering events displayed on an oscilloscope trace. Details of the experimental apparatus are given elsewhere⁴.

Spring and autumn precipitation occurrences have been sampled at temperatures above and below freezing at Laramie, Wyoming. The results are shown in Fig. 1. The liquid water content and amount of loss of crystal structure displayed by melting ice particles can be estimated by surface air temperature, but as several factors may influence the rate at which melting occurs, some dispersion of the data with this temperature value can be expected. The 'total' linear depolarisation ratio, δ_T , has been used to denote the sum of all orthogonal component intensities over the sum of the parallel component intensities obtained from all scatterers observed during each interval, ranging from 112 to 823 (snowflakes) in number. This ratio approximates what would be observed by a polarisation diversity lidar interrogating an equivalent population of scatterers in a single pulse. But, it should be noted that actual lidar data can reflect multiple scattering influences (from scatterings among particles) absent in these measurements which cause an increase in the backscattered depolarised component. The magnitude of this effect on the return from ice particles is still not clear, but will probably be small if lidar design characteristics are used which limit the viewing of multiply scattered radiation⁵.

From Fig. 1, dry snowflakes composed of large aggregates of dendritic ice crystals (hexagonal symbols below 0 °C) can be seen to produce δ_T values near 0.5, the same value as that displayed by populations of small artificial ice crystals⁴. Unrimed and lightly rimed planar and spatial crystals were sampled, with some indication that rimed crystal aggregates produced slightly greater δ_T values. Starting at temperatures slightly above 0 °C, δ_T for melting snowflakes increase to as high as 0.7, demonstrating the presence of an optical wavelength depolarisation bright band analogy. The energy returned from an individual snowflake consists of contributions from ice crystal specular reflections (which retain the polarisation of the source), multiple internal scatterings within a single crystal element, and inter-crystal scatterings. The latter events produce depolarisation through the rotation of the electric field vector of the incident wave. With snowflake melting, three structural changes take place which are believed to induce the increase in depolarisation; ice crystal specular reflecting areas are eroded, compaction of the crystal elements occurs, and a liquid water covering appears on the crystal faces. The alterations have the effect of increasing the highly depolarising inter-crystal scatterings, while subduing specular reflections. The presence of the additional water-ice interface may be particularly effective in increasing the probability of higher order reflections. The manner in which the effects of melting alter the frequency distribution of δ values from individual snowflakes of similar composition is illustrated in Fig 2. Two scattered intensity ranges are shown with the differences between the upper and shaded bars representing, for the most part, the sampling of single crystals or small crystal clusters. A typical dry snow case is shown at the bottom of Fig. 2; a rather narrow δ spectrum peaked near 0.45 with several $\delta \sim 0$ events from scatterings dominated by relatively intense specular reflections from one or more propitiously oriented crystal elements in the snowflakes. With melting, the δ spectra broaden and peak toward higher values. In addition, no $\delta \sim 0$ interactions of large intensity are present in the middle and upper spectra, although some events of small intensity occur. These are thought to result from slow falling crystals or clusters which had completely melted into small, spherical raindrops.

Increases in depolarisation are likely to proceed with melting until the hypothesised collapse of snowflake structure shown in Fig. 1 occurs, producing a rapid δ decrease resulting from the change in geometric cross section. The decline in δ_T from about 4 °C to 6 °C has been proposed to reflect the decreasing asymmetry and ice content of the drops, although only a few data points (depicted by circular and elliptical symbols) have been obtained in this region. Depolarisation is produced primarily as a result of scatterings with the enclosed ice elements. When a sufficient amount of ice has been converted to the liquid phase, the drop will assume a spherical symmetry but lack optical homogeneity. δ_T values for these particles will be low, since a large portion of the light backscattered by spherical particles results from front surface axial reflections and surface waves (responsible for the glory phenomena) which retain the polarisation of the source. A gradual decline in δ_T is thought to occur as the remaining ice content of the drops slowly changes phase. If the resulting raindrops are larger than a few millimetres in diameter, small amounts of depolarised energy may be produced because of the slight distortion in the sphericity of even these mono-phase particles.

Figure 1 also shows data from sampling showers of graupel particles (near spherical, opaque ice particles comprised chiefly of frozen cloud droplets collected during the elements' fall through a dense cloud). The difference in values between melting graupel (triangles) and snowflakes at temperatures >4 °C reflects partly the difference in fall

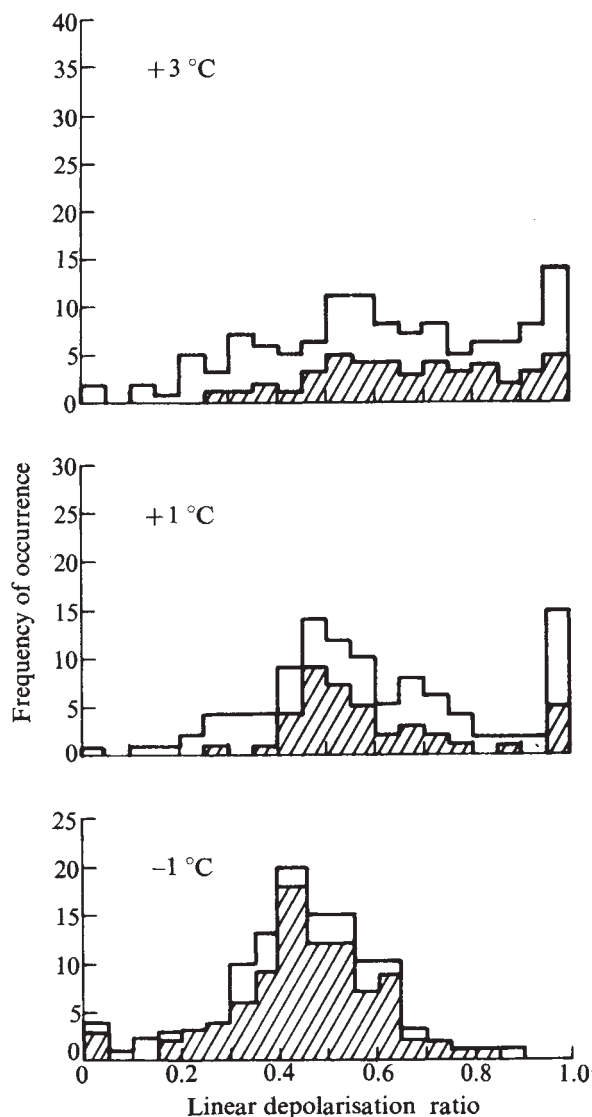


Fig. 2 Histograms of frequency of occurrence of δ values from individual snowflakes obtained from a continuous snowfall situation during which temperatures gradually decreased to below freezing. Changes in behaviour of δ spectra with snowflake melting (from bottom to top) aid in the evaluation of the causes of the depolarisation bright band analogy. Open columns, total scattering interactions; shaded columns, large intensity interactions.

velocities of the two species (since graupel fall at much greater speeds), but also because melting graupel display no fragile extensions, they gradually acquire a thickening liquid covering in contrast to the abrupt snowflake structural transition. A rapid decline in δ_T is suggested from the melting graupel data >6 °C. Although only a few data points are available, uniformly high values are indicated through much of the melting region which do not differ from those obtained at subfreezing temperatures. It is likely that a significant depolarisation bright band will be lacking for melting graupel, but as these particles display a return signature of $\delta_T \sim 0.65$ below 0 °C characteristic of their species, graupel and probably hail shafts as well may be discriminated within or below convective clouds with lidar techniques in suitable conditions.

Although the production of depolarised energy at microwave and optical frequencies is accomplished by vastly different scattering mechanisms, these measurements

demonstrate the presence of a lidar depolarisation bright band analogy, and existing lidar data should be re-examined in the hope of identifying this previously unrecognised phenomenon.

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³ Barge, B. L., *Alberta Hail Studies Report 73-1*, 1–5 (Alberta Research, Edmonton, Canada, 1972).

⁴ Sassen, K., *J. appl. Meteorol.*, 13, 923–933 (1974).

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Palaeomagnetic poles and a Proterozoic supercontinent

PALAEOMAGNETIC evidence does not support the model of a supercontinent made up of Laurentia and West Gondwanaland existing between 2,200 and 1,800 Myr BP. The palaeomagnetic poles (except those based on fewer than 10 samples) from the Laurentian Shield for the interval 2,200 to 1,800 Myr BP are shown in Fig. 1. The poles form a reasonably coherent array stretching from what is nowadays the Mackenzie delta to Peru. This polar path is referred to as polar track 5 (ref. 1), and the sense of apparent polar motion is probably from north to south.

The evidence for this is that the Dubawnt Group (pole D) Kahocella Formation (K), and the Martin Formation (MN) have ages between 1,800 and 1,900 Myr, and are younger than the Indian dikes (IN), which in their turn are younger than the Otto Stock (OS) and the Big Spruce Complex (BS). The age control of the results from the Mugford basalt, Wind River dikes, and the Otish gabbro (poles M, W, and OT) is not so good, but ages of about 2,000 Myr are the most probable. The errors in the results are such that track 5 is not defined as a single line but as a broad zone 15–20° wide. The 15° zone shown in Fig. 1 may correspond approximately to the standard error of the mean ($P=0.67$) position.

The reconstruction of Fig. 1 indicates that about 2,200 Myr ago the Laurentian Shield was at a higher latitude, and this is consistent with the presence of glaciations in the Huronian. The latitude then decreased, and at about 1,800 Myr BP, the latitude ranges from 20–30° over the northern part of Laurentia, which is consistent with the presence of abundant red-beds and carbonates in younger Aphebian strata of the Canadian Shield. This broad correspondence between palaeoclimatic evidence and palaeolatitude indicates that in the interval 2,200–1,800 Myr BP the geomagnetic field was predominantly axial and dipolar. The change in latitude required by track 5 (that is, the minimum movement required) is about 100° at an average rate of about 3 cm yr⁻¹.

One apparent inconsistency in this scheme is the position of the commonly accepted pole for the Nipissing diabase (poles N2, N4, and N6). The Nipissing diabase and the Otto Stock have ages that are not significantly different yet their apparent pole positions are almost 90° apart. Studies of the metamorphic aureole of the Otto Stock have shown that the remanence was acquired during cooling following intrusion¹⁸. But the time at which the Nipissing diabase was magnetised is not known, because a successful contact test and thermal demagnetisation studies have not been described. Much of the diabase has been regionally metamorphosed to low greenschist facies²⁴, and the iron minerals are commonly altered¹⁶. It is possible, therefore, that the remanence postdates the age of emplacement. Moreover the magnetisations observed in Nipissing diabase are complex, and directions other than those corresponding to poles N2, N4, and N6 have been observed (poles N3 and N5). Also

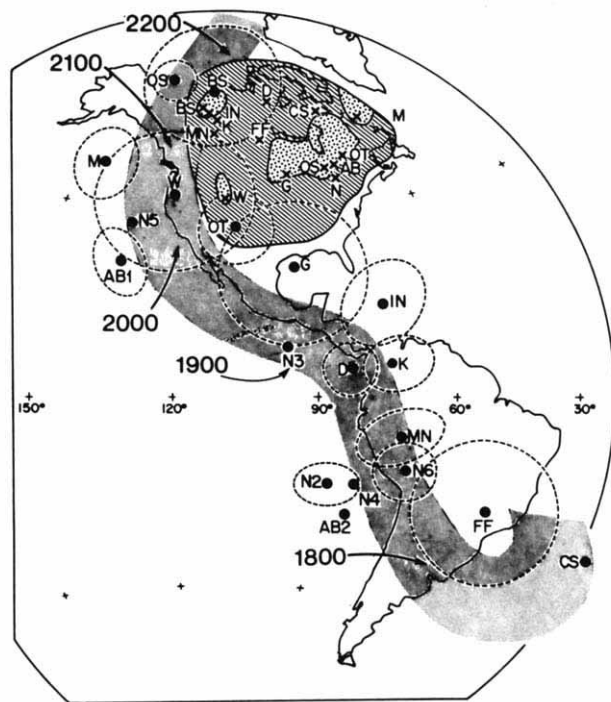


Fig. 1 Track 5. Pole positions for the Laurentian Shield for the interval 2,200 to 1,800 Myr BP. Error circles ($P=0.05$) are given where these can be drawn with some confidence. The Archaean (stippled) and Proterozoic (oblique shading) terrains of Laurentia are distinguished. The poles and the localities from which they were obtained are indexed as follows: AB1 and AB2, Abitibi dikes³, Rb–Sr isochron $2,147 \pm 68$ Myr (ref. 3); D, Dubawnt Group, Rb–Sr isochron $1,830 \pm 26$ Myr (ref. 4); G, Gunflint Formation⁵, $\approx 2,000$ Myr (ref. 6); IN, Indian dikes⁷, Rb–Sr isochron $2,093 \pm 86$ Myr (ref. 3); K, Kahocella Formation, Rb–Sr isochron from associated volcanics $1,873 \pm 13$ Myr (ref. 8); M, Mugford basalt⁹, preliminary Rb–Sr isochron $\approx 2,300$ Myr (ref. 10); MN, Martin Formation, K–Ar on associated dikes $1,835$ Myr (ref. 11). Nipissing diabase: Rb–Sr isochrons^{12,13} $2,160 \pm 60$ and $2,150 \pm 50$ Myr; five pole determinations N2¹⁴, N3¹⁵, N4 (selected site from ref. 14), N5¹⁴, N6¹⁶. OT, Otish gabbro¹⁷, age from indirect evidence $\approx 2,000$ Myr; OS, Otto Stock¹⁸, Rb–Sr isochron¹⁹ $2,160 \pm 80$ Myr¹⁹; W, Wind River dikes²⁰, maximum K–Ar age $2,060$ Myr; CS, Volcanics of Cape Smith Belt²¹ age uncertain but in the range 1,800 to 2,000 Myr, the lower limit being the probable age of metamorphism (the preferred age of magnetisation); BS, Big Spruce Complex²², Rb–Sr isochron $2,170 \pm 40$ Myr (ref. 23); FF, Flin Flon intrusions and metamorphic rocks²⁴ Rb–Sr isochrons $1,775 \pm 89$ and $1,805 \pm 14$ Myr.

the Abitibi dikes have one dominant (corresponding to pole AB1) and one subordinate (AB2) magnetisation, although the ages of the rocks from which they were derived are not significantly different³. Poles AB1 and N5 are close together, as are poles AB2, N2, N4, and N6. N3 falls between the two groups. Thus the magnetisations of the Abitibi and Nipissing diabases may be a complex mixture of as yet unresolved primary and overprinted magnetisations. The positions of the Abitibi and Nipissing diabase poles available at present may be regarded as uncertain, and all that can be said is that they probably lie near track 5.

The poles of track 5 are derived from many different parts of the Laurentian Shield, including the four Archaean blocks marked on Fig. 1 (the Superior Province—the largest, the Slave Province (marked BS), the Bear-tooth uplift (W), and the Labrador coastal section of the North Atlantic craton (M)). There are only single poles, with ages that are not well established, from M and W (Fig. 1), and clearly many more data are required. The Slave–Superior comparison is better documented, and the excellent agreement between poles for the Big

Spruce Complex (BS) and the Otto Stock (OS) which have similar ages, is notable.

The general coherence of the poles implies that these blocks did not move by very large amounts relative to one another during the Hudsonian orogeny. This does not mean that relative movement definitely did not occur, because there are many uncertainties in the palaeomagnetic data. Because of the errors in pole determinations track 5 is not a single line but a broad zone, so that opening and closing of small oceans with dimensions of the order of 1,000 km would go undetected. Moreover, relative motion in a purely longitudinal sense cannot be detected palaeomagnetically; that is, if the Eulerian pole defining the relative motion of two land masses coincides with the palaeomagnetic pole then the relative motions will have no palaeomagnetic expression. If, for example, relative motion of the Slave and Superior Archaean blocks had occurred it would not be seen palaeomagnetically if the motion had been in a longitudinal sense relative to the palaeomagnetic pole. The presence of a single polar track does not therefore necessarily imply that there has been no relative motions among the Archaean cratons; it simply means that the hypothesis of no motions is the simplest but not the only explanation of the results.

The evidence of Fig. 1 suggests that from about 2,200 to 1,800 Myr BP the Laurentian Shield moved at rates comparable with present-day plate motions. The approximate coherence of the polar array indicates that the relative movements among the Archaean cratons were at least several times less than the movement of the whole relative to the pole (100°). It is therefore to be expected that marginal deformation akin to Phanerozoic plate tectonics occurred, and the Coronation geosyncline and the associated Great Slave aulacogen is probably of this nature²⁵. During this time linear basins were formed within the

of Fig. 1 seems to confirm partly, if only in tentative fashion, their hypothesis.

It has been suggested^{27,28} that a common Proterozoic polar path could be reconstructed for West Gondwanaland (Africa and South America) and Laurentia, so that these cratons formed a single continent from about 2,200 to 1,000 Myr BP. This path and continental reconstruction is shown in Fig. 2 (polar path A). Track 5 is superimposed and there is marked disagreement. The poles from the Otto Stock and Big Spruce Complex (poles OS and BS of Fig. 1 at the 2,200 Myr calibration point of track 5 in Fig. 2) are about 90° away from poles of similar age (Tarkwaian intrusions and Obuasi greenstone²⁹ near to the 2,200 Myr calibration point of polar path A of Fig. 1) from Africa. We conclude that the palaeomagnetic evidence, as it is known at present, does not support the idea of a Proterozoic supercontinent comprising Laurentia and West Gondwanaland in the interval 2,200 to 1,800 Myr BP. Regarding the palaeomagnetic evidence for the existence of a supercontinent during the later Proterozoic, especially in the interval 1,400 to 1,000 Myr BP for which the evidence has been deemed the strongest^{27,28}, it is noteworthy that other reviewers^{30,31} have argued that the polar curves for this interval from North America and Africa cannot be satisfactorily superimposed, and the critical evidence cited in favour of such a reconstruction^{27,28} has not yet been published.

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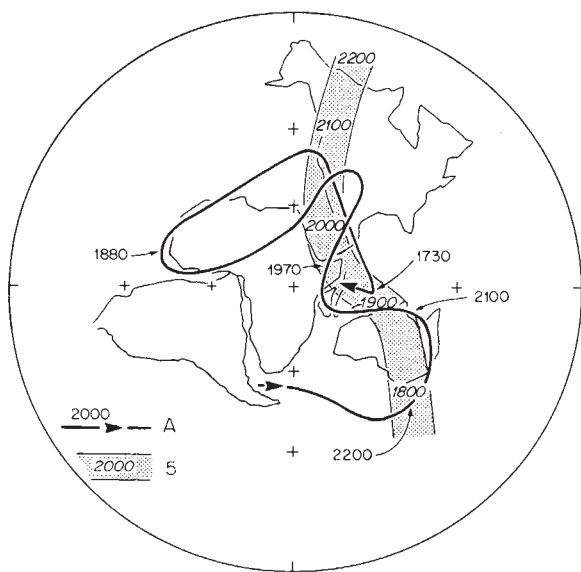


Fig. 2 Polar tracks for interval 2,200 Myr BP to 1,800 Myr BP from West Gondwanaland (A) and Laurentia (5) compared. The continental reconstruction and polar path (A) is from refs 27 and 28. Track 5 is from Fig. 1.

Laurentian Shield, and they became filled with deposits. These deposits were deformed in the Hudsonian orogeny, which is related in time to the orogeny that affected the Coronation geosyncline. Thus the Laurentian Shield seems to have undergone intense internal deformation but without loss of general coherence; it does not seem to have been as rigid as the continental parts of modern plates.

This discussion regarding the nature of Hudsonian orogenesis is consonant with that of Sutton and Watson²⁶ and the evidence

Dispersion of alcohols and water in the submillimetre waveband

FOURIER spectroscopy using polarisation¹ and cube^{2,3} Michelson interferometers has made possible the study of the dispersion of aliphatic alcohols^{4,5} and water⁶ in the submillimetre waveband of the electromagnetic spectrum. Table 1 enumerates measurements we are reporting of refractive index n and absorption coefficient α ; the most significant new alcohol and water data are displayed graphically in Fig. 1. The alcohol absorption bands seem to shift in frequency and broaden somewhat as the chain length increases. Alcohols show a monotonic fall of

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refractive index between 20 and 150 cm^{-1} , but at higher frequencies it remains substantially frequency invariant. The individual dispersions arising from each absorption band cannot easily be discerned.

The absorption function for *tert*-butyl alcohol is different, presumably because the degree of chain polymerisation is uniquely small; the additional band at 70 cm^{-1} is probably caused by Poley absorption in the liquid which consists principally of monomers and dimers.

In the case of water, it has been proposed⁶ that the monotonic fall of refractive index can be understood in terms of dielectric relaxation and that the absorption bands are superposed on a Debye relaxation. It is useful to carry out the same exercise on aliphatic alcohols as was carried out for water: calculation from the present data of the complex permittivity function $\hat{\epsilon}(\omega)$, and subtraction of the contributions to $\hat{\epsilon}$ from the principal relaxation, calculated using radiofrequency data from Garg and Smyth⁷ and others. Corrected $\hat{\epsilon}(\omega)$ for water, ethyl alcohol and 1-butanol are presented graphically in the form $\epsilon''(\epsilon')$ in

Fig. 1 Measured optical constants at 20 °C of water and primary aliphatic alcohols as functions of wavenumber $\bar{\nu}$. Numbers indicate numbers of carbon atoms in molecule; for example curves 4 are for 1-butanol; curve 4' is for *tert*-butyl alcohol. a, Alcohol refractive indices n ; b, alcohol absorption coefficients α ; c, absorption coefficient and refractive index of water.

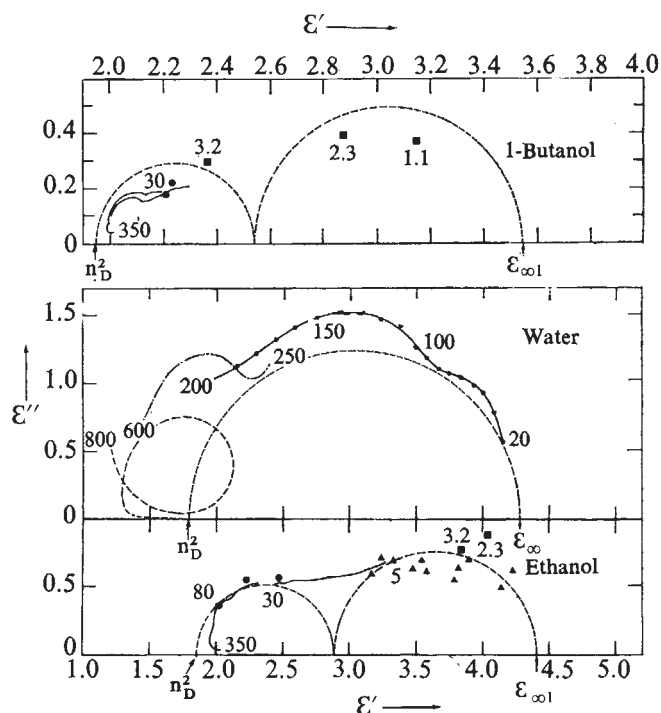
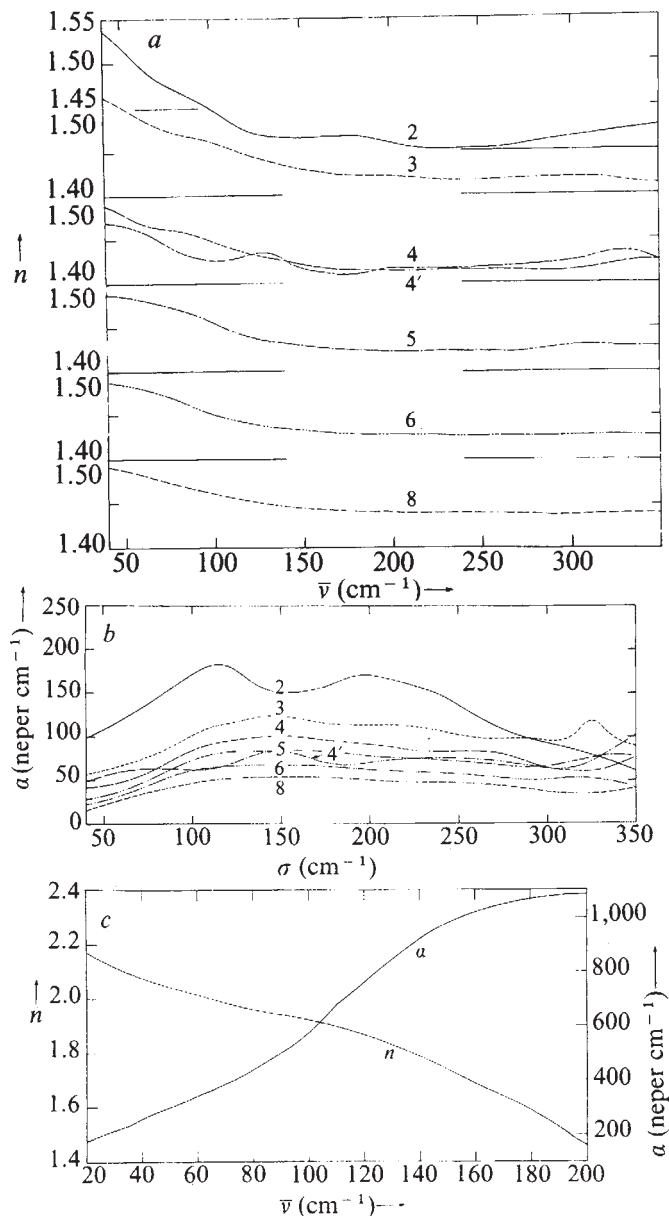


Fig. 2 $\epsilon''(\epsilon')$ representations of permittivities of 1-butanol, water and ethanol with contributions from the principal relaxation processes subtracted. Numbers represent wavenumbers in cm^{-1} . —●—, Our data; —○—, data of ref. 7; —■—, data of ref. 8; —▲—, other unpublished data.

Fig. 2. In this representation a Debye relaxation appears as a semicircle on the ϵ' axis, ranging from the principal relaxation value $\epsilon_{\infty, 0}$ to the optical value $n_D^2, 0$. Absorption bands appear as arcs of smaller circles ("curleques") superposed at the high frequency end of the semicircle. The errors in ϵ'' arising from inaccuracies in the calculation of the contribution from the principal relaxation time are difficult to estimate adequately; but they may be as large as $\pm 30\%$ when ϵ' is close to $\epsilon_{\infty, 1}$, falling to less than 1% when the maximum value of ϵ'' is reached.

The new data for water cover a wider frequency range than earlier⁶ data, and are of improved accuracy: the discrepancy⁶ between ϵ_{∞} calculated from the principal relaxation and that calculated from the proposed high frequency relaxation disappears in the present data. The recent data of Curnutte and Williams⁸ from 250 to 800 cm^{-1} are included in Fig. 2, but their absorption coefficients are not shown in the region below 250 cm^{-1} , where they are higher than the present data; the interpretation as a sum of relaxation and resonance processes is not invalidated by this discrepancy.

Alcohols have been supposed⁷ to exhibit two separate relaxation processes in the millimetre wave region; to test the validity of this proposal trial semicircles have been drawn, from $(\epsilon_{\infty, 1}, 0)$ to $(\epsilon_{\infty, 2}, 0)$ and from $(\epsilon_{\infty, 2}, 0)$ to $(n_D^2, 0)$. For ethanol there is sufficient microwave data for this interpretation to appear possible, but the situation in the other cases, of which 1-butanol is a typical example, is far from clear, and there is a need for further millimetre wave data before such a proposal can be evaluated. It would be quite possible to represent the 1-butanol data and even those for ethanol by a spread of relaxation times.

Alcohol molecules have been considered⁹ to be chain-linked by hydrogen bonds, with principal relaxation activation enthalpy sufficiently large for hydrogen bond breakage. A comparison of the present ethanol data with the low temperature data of Hasson and Cole⁹ shows that the activation

Table 1 Refractive index and absorption coefficient data

Wavenumber range (cm ⁻¹)	Measured quantity	Technique	Author									
				Water	Methanol	Ethanol	Propanol	<i>n</i> Butanol	<i>tert</i> -butyl alcohol	Pentanol	Hexanol	Octanol
20–100	α	Melinex beam divider Transmission technique Variable thickness cell Quartz window	GJD			×	×	×	×	×	×	×
20–100	α	Melinex beam divider Transmission technique Fixed thickness cell Quartz window Reflection losses not computed, α expected to be low	GJD	×	×							
20–120	n	Melinex beam divider Subtraction technique ^{4,12}	MNA			×	×	×		×	×	×
20–220	n	Polarisation interferometer	MNA					×	×			
5– 30	α, n	Polarisation interferometer	MNA		×	×						
20–350	α	Melinex beam divider, quartz and Rigidex window Transmission technique, Variable thickness cell	MSZ			×	×	×	×	×	×	×
29.7	α, n	HCN laser, transmission technique	MSZ	×	×	×	×	×		×	×	×
40–350	α, n	Melinex beam divider Subtraction technique Improved computation from dispersive interferogram	MNA			×	×	×	×	×	×	×
20–200	α, n	Reflection technique Melinex beam divider TPX window	MNA	×								
85	n	H ₂ O laser, reflection technique	MSZ	×	×	×	×	×		×	×	×
85	n	H ₂ O laser, transmission technique	MNA, MSZ				×	×		×	×	×

enthalpy of the first high frequency relaxation process is similar to that for the principal relaxation; this agrees with their proposal that these two processes correspond to the "symmetrical" and "unsymmetrical" hydrogen bond mechanisms also proposed for water^{10, 11}

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²¹⁰Po and ²³⁹Pu, ²⁴⁰Pu in biological and water samples from the Bikini and Eniwetok atolls

MEASUREMENTS of the radioactivity in water and biological samples from Bikini and Eniwetok lagoons indicate that although the samples were collected from the most plutonium-polluted waters of the world, the values of the naturally produced radionuclide, polonium-210 were usually greater than the values of plutonium-239 and 240, which are produced by nuclear detonations by factors as great as 100.

With the advent of nuclear testing at the Bikini and Eniwetok atolls in the central Pacific, an environmental laboratory became available for investigating the concentrations of many radionuclides in the marine environment and their uptake by biota. Over the 16 years since the conclusion of nuclear testing, the long lived radionuclides created during the tests and deposited in sediments have had time to approach equilibrium with biota and with natural radionuclides present.

It is of particular interest to compare the concentrations of natural radionuclides, such as ²¹⁰Po, with concentration of ²³⁹Pu and ²⁴⁰Pu produced by nuclear bombs, in that part of the world which has been subject to most radioactive fallout. Both radionuclides decay by α -particle emission of approximately equal energy and both become concentrated in biota. The amount of plutonium to be used in nuclear power reactors is expected to increase by a factor of 1,000 in the next 30 years¹ and with this increased use comes the possibility of accidental or planned releases of plutonium

Table 1 ^{210}Po , ^{239}Pu and ^{240}Pu values in biological and water samples, and the corresponding concentration factors for samples collected in October, 1972 at Bikini and Eniwetok atolls

Species and tissue	Biological samples		$^{239,240}\text{Pu}$ * (d.p.m. g ⁻¹ , wet)	Water samples		$^{239,240}\text{Pu}$ (d.p.m. m ⁻³)	Concentration factor	
	Location	^{210}Po range* (d.p.m. g ⁻¹ , wet)		Location	^{210}Po (d.p.m. m ⁻³)		^{210}Po range	$^{239,240}\text{Pu}$
Turtle liver (1)†	Eniwetok rubbish dump dock	0.20–0.69	0.200	Runit dock	188 ± 40	190 ± 11	(1.1–3.7) × 10 ³	1.1 × 10 ³
Goatfish viscera (6)	Eniwetok, Runit seaward reef	2.60–9.27	0.650	200 yards off Runit	146 ± 20	190 ± 11	(1.8–6.3) × 10 ⁴	3.4 × 10 ³
Wavyback skipjack (1), dark muscle	Eniwetok Lagoon	2.50–8.94	0.280	„ „	146 ± 20	190 ± 11	(1.7–6.1) × 10 ⁴	1.5 × 10 ³
Mullet (2) eviscerated whole	Eniwetok, Runit seaward reef	0.50–1.90	0.003	„ „	146 ± 20	190 ± 11	(3.4–13) × 10 ³	16
Surgeon fish (3), bone	Bikini a-6	8.15–49.70	<0.001	b-15	107 ± 10	73 ± 9	(7.6–46.0) × 10 ⁴	<20
Surgeon fish (3), muscle	Bikini a-6	0.02–0.15	<0.001	b-15	107 ± 10	73 ± 9	(1.9–14.0) × 10 ³	<20
Surgeon fish (1), eviscerated whole	Bikini a-2	0.40–2.50	0.018	b-2	124 ± 13	138 ± 9	(3.2–20.0) × 10 ³	130
Surgeon fish (3), viscera	Bikini a-6	0.51–3.09	1.330	b-15	107 ± 10	73 ± 9	(4.7–29.0) × 10 ³	1.8 × 10 ⁴
Convict surgeon (3), muscle	Bikini a-3	0.10–0.59	<0.001	b-6	125 ± 13	51 ± 7	(8.0–47.0) × 10 ³	<20
Convict surgeon (17), muscle	Bikini a-7	0.06–0.34	<0.001	b-18	145 ± 14	102 ± 9	(4.1–23.5) × 10 ³	<20
Convict surgeon (13), muscle	Bikini a-4	0.13–0.77	<0.001	c-12	135 ± 14	45 ± 5	(9.6–57.0) × 10 ³	<20
Convict surgeon (6), muscle	Bikini a-5	0.09–0.56	<0.001	b-10	153 ± 15	7 ± 2	(5.9–36.5) × 10 ³	<20
Convict surgeon (13), eviscerated whole	Eniwetok, Runit seaward reef	0.80–2.75	0.005	200 yards off Runit	146 ± 20	190 ± 11	(5.5–19) × 10 ³	26
Convict surgeon (21), eviscerated whole	Eniwetok, Runit	0.20–3.31	0.025	„ „	146 ± 20	190 ± 11	(1.4–22.6) × 10 ³	130
Convict surgeon (4), eviscerated whole	Bikini a-2	1.40–8.28	0.028	b-2	124 ± 13	138 ± 9	(1.1–6.7) × 10 ⁴	200
Convict surgeon (1), eviscerated whole	Bikini a-1	0.46–2.82	0.010	c-3	141 ± 15	138 ± 9	(3.3–21.7) × 10 ³	72
Convict surgeon (4), eviscerated whole	Bikini a-1	0.34–2.06	0.017	c-3	141 ± 15	138 ± 9	(2.4–14.6) × 10 ³	120
Convict surgeon (17), liver	Bikini a-7	2.04–12.50	0.913	b-18	145 ± 14	102 ± 9	(1.4–8.6) × 10 ⁴	9 × 10 ³
Convict surgeon (21), viscera	Eniwetok, Runit seaward reef	1.20–4.20	0.140	200 yards off Runit	146 ± 20	190 ± 11	(8.2–28.7) × 10 ³	7.4 × 10 ³
Convict surgeon (13), viscera minus liver	Bikini a-4	1.67–10.21	0.350	c-12	135 ± 14	45 ± 5	(1.2–7.6) × 10 ⁴	7.8 × 10 ³

*Analytical error is ±10% for polonium and ±20% for plutonium.

†Numbers in parentheses indicate the number of fish or organs combined in a given sample. Concentration factors are calculated as a ratio of activity per gram of wet tissue to activity per gram of water.

into the food chain of man. The uptake of plutonium by biota in the marine environment is not well understood and a full evaluation of their potential hazard cannot yet be made.

Natural waters contain ^{210}Po as a member of the ^{238}U decay chain. Atmospheric aerosols also contain ^{210}Po which are scavenged² by precipitation and enter the hydrosphere. Once in the aquatic environment, polonium and plutonium undergo processes such as precipitation, redistribution, and changes in physical-chemical and oxidation states which may not be similar for the two elements. Both, however, are apparently available biologically as they are accumulated by algae, phytoplankton, zooplankton, vertebrates and invertebrates^{3–8}.

The samples discussed here were collected by the Laboratory of Radiation Ecology (LRE) during the 1972 joint expedition with the Puerto Rico Nuclear Center and the Lawrence Livermore Laboratory to Bikini and Eniwetok atolls. The locations of the collecting stations are shown in Fig. 1. The analytical results and collection locations of both biological and water samples, and the number of individual species of biological samples measured, are given in Table 1. Samples labelled as 'eviscerated whole' are whole fish which have had the viscera (liver, kidney, gonads, gut contents, and gastrointestinal tract) removed.

As several months elapsed between the collection and analysis of samples, the disintegration rate of ^{210}Po was corrected to allow for decay between the date of counting and the date of collection. The lower and upper limits given in Table 1 indicate the possible range of values if,

first, ^{210}Po was derived entirely from the decay of ^{210}Pb in the sample (the lower limit) or, second, no ^{210}Pb was present and the ^{210}Po measured was the true concentration present at the sampling time (the upper limit). The real value is expected to be near the upper limit for most samples since, in pelagic fish, the ^{210}Po is obtained by direct uptake and not as much by ingrowth from ^{210}Pb ; measurements showed 1–5 times more ^{210}Po than ^{210}Pb (refs 8–10).

Table 1 shows that ^{210}Po activity is highest in bone, decreasing in order in liver, viscera and muscle. Although bone and liver have been reported as the major repositories for plutonium¹⁰, the plutonium content of the single bone samples reported was at the detection limit of 0.001 d.p.m. per g, wet weight. The high concentrations of both ^{210}Po and ^{239}Pu and ^{240}Pu in viscera and viscera minus liver (convict surgeon), together with the fact that algae in the diet of these species concentrates those radionuclides from seawater, seems to support the idea that both radionuclides enter the fish during the ingestion of food.

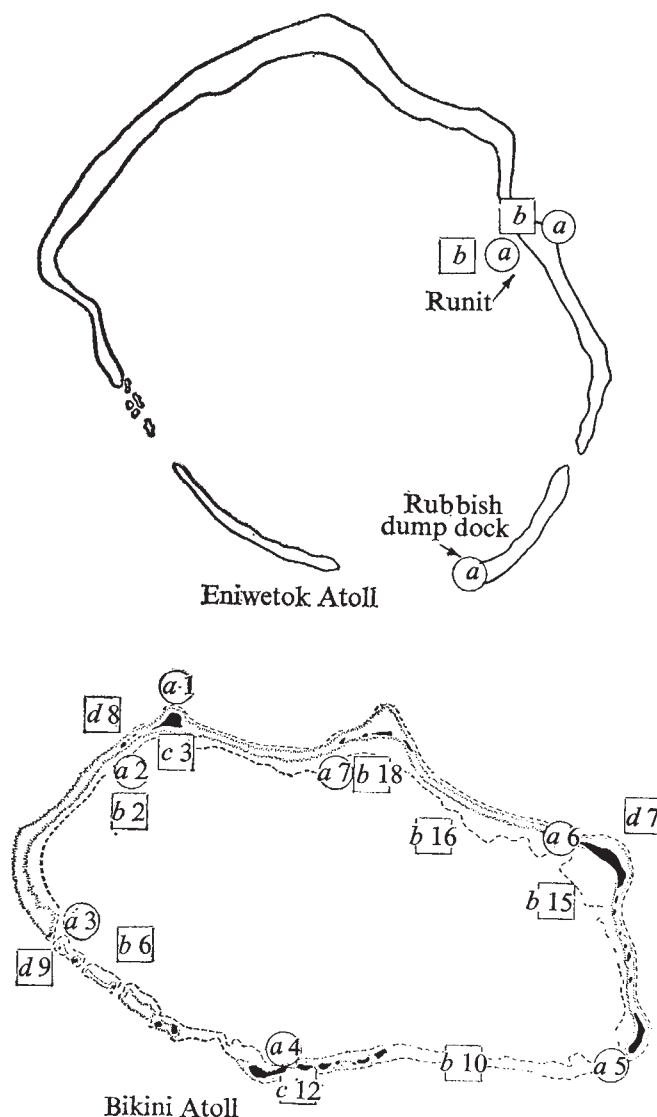
Values of plutonium radioactivity have been reported in a large number of biological samples from Eniwetok Atoll¹¹. These data also show that the highest plutonium concentrations occur in the viscera of fish. The food contents of the digestive organs were not separated, however, so it is not possible to estimate what fraction of the activity is associated with food and how much occurs in the tissues or organs of the fish.

The convict surgeon and surgeon fish were selected for ^{239}Pu , ^{240}Pu and ^{210}Po analysis because they are local feeders and would concentrate radionuclides from nearby waters.

The concentrations of ^{239}Pu , ^{240}Pu and ^{210}Po measured in water from near the sites of the fish collection were used to determine the concentration factors shown in Table 1. The ^{210}Po concentration in the water was calculated from the ^{210}Pb concentration measured in the samples after most of the ^{210}Po had decayed. The error on the ^{210}Po calculation is expected to be small, as the ratio of $^{210}\text{Po}/^{210}\text{Pb}$ is approximately 1:2 in seawater^{8,9}; thus, the ^{210}Pb and ^{210}Po would be near secular equilibrium in the marine environment at Bikini and Eniwetok atolls. The highest ^{239}Pu and ^{240}Pu contents in the water column were found in areas where the highest activity of those radionuclides occurred in sediments, as reported already for Bikini¹². The highest ^{210}Po concentration was found outside the lagoon in the deep ocean waters, and one possible explanation could be that biological uptake results in a shorter resident time of ^{210}Po - ^{210}Pb in the lagoon. The concentration of ^{210}Pb in the particulate phase, ($>0.3\ \mu\text{m}$ in size) was less than 10% of the total; the concentrations of ^{239}Pu and ^{240}Pu in the particulate phase varied from 2 to 60% of the total depending on where it was collected from¹². The overall result indicates that inside the lagoon the radioactivity values of plutonium were more variable than those of ^{210}Po .

Concentration factors of ^{210}Po , ^{239}Pu and ^{240}Pu in organisms (Table 1) are calculated using the total concentrations

Fig. 1 Sampling stations at Bikini and Eniwetok atolls. *a*, Intertidal zone, biological stations; *b*, lagoon stations; *c*, crater stations; *d*, ocean stations.



(particulate plus soluble) measured in the water. All specimens measured have concentration factors for ^{210}Po that are greater (as much as 100 times greater) than those for ^{239}Pu and ^{240}Pu with the exception of samples of turtle liver and surgeon fish viscera. Although these samples were collected in the most plutonium-polluted waters of the world we conclude that the plutonium radioactivity is only a fraction of the natural polonium radioactivity, and that a greater radiation dose to the marine organisms of Bikini and Eniwetok lagoons would be received from ^{210}Po than from ^{239}Pu and ^{240}Pu . This conclusion should not, however, lead to neglect in studies of plutonium concentrations in the higher trophic levels and of its transport through the food web to man.

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r and K selection in kangaroos

MACARTHUR and Wilson¹ used the terms 'K selection' and 'r selection' to describe two general kinds of selection they believed could be functioning in nature. Where there is no crowding, evolution favours productivity (r selection). Alternatively in a crowded situation where some resource is scarce, evolution favours the efficient use of this resource in the production of offspring (K selection). Thus r selection occurs when it is more important to increase numbers and K selection when population size is near the maximum that can be carried in the prevailing environmental conditions. Pianka² summarised a number of theoretical correlates of r and K selection, and some of these are given in Table 1.

Reports on natural situations in which r or K selection can be expected to have occurred in closely related organisms are quite rare in the literature and here I describe one such example. The kangaroos and wallabies of Australia form a cohesive group with a relatively recent origin³. The amount of genetic divergence between species is fairly limited since viable, though infertile, hybrids are found between many members of the group⁴. The animals occur in a wide range of habitats, however, including the extremely unpredictable low rainfall environment of central Australia and the more stable environment of the eastern forests. The red kangaroo (*Macropus (Megaleia) rufa*) is found in the former and the eastern grey kangaroo (*Macropus (Macropus) giganteus*) in the latter³. These two similarly sized species provide an interesting comparison because the red kangaroo should be subject to predominantly r selection and the eastern grey kangaroo to predominantly K selection. The relevant ecological data for these two species are summarised in Table 1.

The fit of the data to those suggested on theoretical grounds is quite good. The red kangaroo is clearly adapted

Table 1 Summary of some theoretical correlates of r and K selection and relevant data on the red and eastern grey kangaroos

Item	r selection		K selection	
	Theoretical ²	Red kangaroo	Eastern grey kangaroo	Theoretical ²
Climate	Variable or unpredictable	Arid zone (unpredictable)	Forest (more constant than for red kangaroo)	Fairly constant or predictable
Mortality	Catastrophic, non-directed, density independent	Catastrophic (drought) Depending on conditions young leaving pouch either all die or almost all survive	Rarely catastrophic. Normally 50% of young leaving pouch die by 15 months*	Fairly constant, at or near carrying capacity
Intraspecific competition	Lax	Population usually well below carrying capacity	Populations near carrying capacity*	Keen
Interspecific competition	Lax	Sympatric with three other large macropodids	Sympatric with eight other large macropodids	Keen
Selection favours:	Rapid development	Gestation ³ 33 d, pouch life ³ 235 d, suckle until 14 months of age†	Gestation ⁴ 36 d, pouch life ⁴ 319 d, suckle until 18 months of age†	Slower development
	High r^{max}	Continuous opportunist breeder ³ , delayed blastocyst ³ (In drought, discard pouch young while small and replace, maintaining mother's condition ⁵)	Usually seasonal breeder ³ , partially delayed blastocyst ³ (In drought carry pouch young until mother almost in extremis*)	Lower resource threshold
	Early reproduction	As soon as conditions permit after reaching 18 months of age†	When good conditions occur at the beginning of the first breeding season after reaching 18 months of age (often wait, 1, 2 or more years)†	Late reproduction
	Mobile‡	Mobile in bad seasons ³	Sedentary ³	Sedentary‡

*T. Kirkpatrick (personal communication).

†W. E. Poole (personal communication).

‡B. S. Richardson (personal communication).

for a rapid population recovery following a bad drought, whereas the grey kangaroo is adapted to producing young best able to enter the adult population in the face of competition for limited resources. In this sense the pattern seen in the grey kangaroo does not fit that originally described for K selection. Here the pressure is not on the mother to find sufficient of the limiting resource to produce a youngster ready to enter the population but on the youngster, on permanently leaving the pouch to make a place for himself in the adult population. Thus in the original forest habitat it seems likely that less than 10% of eastern grey kangaroos leaving the pouch survive the next 6 months (T. Kirkpatrick, personal communication). In this case K selection involves production of a young animal best able to fight for its place, rather than efficiency of the mother to convert the resources into young (that is, economy). It seems likely that the patterns suggested by Pianka² for K selection when energy is the limiting factor will not necessarily be satisfactory for other resources, for example, when space is the limiting factor. In the grey kangaroo selection may favour the doe who is quite profligate with her time and energy (not limiting) if this increases her offspring's chance of survival over a doe who produces more young. It would depend on the role chance plays in the choice of the survivor.

Note that since the European settlement of Australia the eastern grey kangaroo has extended its range many hundreds of miles westward into the dry inland zone occupied by the red kangaroo. This seems to be at least partly caused by the supply of stock watering points and the more predictable nature of this environment which results. The red kangaroo has an advantage over the eastern grey kangaroo in this area only during extended severe droughts (ref. 3 and T. Kirkpatrick, personal communication). Also the numbers of both species of kangaroo in this area have increased greatly this century³ and, if the species is in direct competition for a limited resource, the eastern grey kangaroo should be at an advantage. Culling by professional hunters may, however, stop the populations reaching any resource limit in these areas.

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Effect of simulated 'acid rain' on cation loss from leaves

INCREASING consumption of fossil fuels over the past two decades has given rise to elevated levels of nitrogen and sulphur oxides in the atmosphere. These compounds undergo hydrolysis and oxidation giving rise to nitric and sulphuric acids. The presence of these compounds in precipitation may enhance its hydrogen ion concentration¹. Normally, precipitation has a pH range of 6.5-7.0 but the trend towards increasing acidity is increasingly clear. pH values of 4.0 have been reported for Cumbria, UK², 3.8-4.2 for Liverpool, UK (M. H. Eastwood, personal communication), approaching 3 for Hubbard Brook, New Hampshire¹, and a value of 2.8 has been recorded in Scandinavia¹. One of the main effects of rainfall on plants is the leaching of nutrients from leaves. What effect rainfall of low pH may have on this process is at present unknown, as previous leaching studies³ have used distilled water at pH 6-7.

Little attention has been paid to the effects of 'acid rain' on vegetation, possibly as a result of the absence of visible injury at pH values similar to those recorded in rainfall. Experiments reported by Wood and Borman⁴ on growth of

yellow birch seedlings in relation to pH of artificial mist, revealed foliar spot and marginal necrosis of leaves at pH 2.3. At pH levels above this, no foliar injury was reported. Sheridan and Rosenstreter⁷ demonstrated a decrease in photosynthetic rate in the moss *Tortula ruraliformis* in response to increasing acidity of rainfall. Concomitant with this was a reduction in the ratio of chlorophyll A/chlorophyll B, and a sharp decline in respiration rate below pH 3. Gordon (cited in ref. 5) demonstrated that the developmental malformation of pine termel 'short-long needle disease' occurred in response to a range of rainfall of pH between 1.5 and 4.5.

We investigated nutrient losses from leaves in response to pH of rainfall. Tobacco plants (*Nicotiana tabacum* L. var virginiana) of the same age were selected, and leaves at the same state of maturity were used for leaching. One batch was leached with deionised water at pH 6.7, whereas the second batch of plants was leached with H₂SO₄ adjusted to pH 3.0. Leaching techniques were similar to those used by Tukey *et al.*³, except that our leaching rates were slightly lower, being maintained at 400 ml h⁻¹ over a 6-h experimental period. The relationship of these leaching rates to natural precipitation rates will be dependent on local precipitation data, and as these may vary considerably from area to area, no exact relationship between the laboratory experiment and field precipitation levels can be given. Leached cations were collected on columns of Zerolit 325 cation-exchange resin. Samples of the leaching solution were passed through similar columns with the same rate and time period to measure background cationic levels in the leaching solutions. Cations were eluted from the resin columns using 10% HCl, and eluate cation concentrations assayed for K⁺, Ca²⁺ (by flame photometry) and Mg²⁺ (by atomic absorption spectrophotometry). In experiments with 'acid rain' at pH 3, a correction factor was calculated for each ion to allow for loss of efficiency of the ion-exchange resin in retention of cations at an elevated H⁺ concentration.

Table 1 Cation loss from *Nicotiana* leaves in relation to pH of leaching solution

pH of leaching solution	K ⁺	Leached cation Ca ²⁺	Mg ²⁺
6.7	58±16	73±18	3.4±1.4
3.0	13±4.8	273±66	4.6±2.0
Significance	*	*	—

Cation concentrations are given in µg cation leached per leaf per 6-h wash. All experimental leaves were fully expanded and 8 weeks old. Values represent the means of 21 replicated ± s.e.

*Probability of the two means being equal is less than 0.01. Significance was calculated using a *t* test for groups of equal sizes⁸.

Table 1 shows that increases in foliar Ca²⁺ loss occur in response to a decrease in rainfall pH, whereas losses in K⁺ decrease. Little change occurs in levels of Mg²⁺ lost. Mecklenburg *et al.*⁷ demonstrated that Ca²⁺ loss from leaves occurs by a passive process of ion exchange, in which H⁺ in rainfall exchange with foliar Ca²⁺, resulting in the loss of the latter. Consequently, Ca²⁺ losses from leaves will be solely dependent on H⁺ concentrations in rainfall. This agrees well with the data in Table 1, in which increased Ca²⁺ loss occurs with increasing H⁺ concentration. The decrease in K⁺ loss with increasing H⁺ concentration is less readily explained. Tukey *et al.*³ have demonstrated that Ca²⁺ is more readily leached than K⁺, using distilled water; as most H⁺ may be used to release Ca²⁺, this could leave fewer to replace K⁺.

An alternative explanation is that of physiological damage caused by 'acid rain'. Rains *et al.*⁸ have suggested that hydrogen ions may damage the selective uptake mechanism for K⁺ in root cells, the integrity of this mechanism being protected by Ca²⁺. If Ca²⁺ levels are de-

pleted and replaced by H⁺, then a subsequent reduction in K⁺ uptake could lead to a decrease in K⁺ available for leaching. Mecklenburg and Tukey⁹ have also demonstrated that the most recently absorbed Ca²⁺ are most readily leached; so in view of the slow upward movement of Ca²⁺ (10 cm d⁻¹)¹⁰, the possibility of rapid depletion of freely exchangeable Ca²⁺ is likely. The reason for the increased retention of K⁺ in the 'acid rain' regime is certainly elusive, and any explanation is only tentative. Other factors, at present unknown, may be operating to regulate these levels.

These results imply that increasing Ca²⁺ loss may occur from leaves with increase in H⁺ content of precipitation. Several questions must be answered before the importance of these observations can be fully evaluated. These include measurements of cation loss from different species in different pH regimes, and a characterisation of the form in which Ca²⁺ is lost from leaves. 'Acid rain' contains free SO₄²⁻, and Ca²⁺ lost from foliage may react with this to form insoluble CaSO₄. This could have considerable implications in the natural cycling of this element in polluted ecosystems. Further experiments are in process to clarify these points.

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Mate selection in Pacific tree frogs

DARWIN¹ suggested that, in many animal species, females select mates and that some male courtship displays and secondary sex characters are a product of this sexual selection. Although the importance of sexual selection is generally acknowledged², only a few studies have shown both that females prefer certain males and also that this preference is a function of male display behaviour, for example, studies of polygamous birds³ and fruitflies⁴. We have observed that in the Pacific tree frog (*Hyla regilla*), females mate preferentially with certain males, and that this preference is related to differences between males in calling behaviour.

The males congregate during the spring in ponds and lakes where they call, mostly at night, for several months. Within a local area, such as a small pond, males space themselves at least 50 cm apart (C.L.W. and J.R.K., unpublished) and call in bouts. Typically, all males call for a few minutes, then all are silent for a few minutes before calling again. Attracted by the calls⁵, females approach individual males, and only when a female nearly touches a male does he cease calling and attempt amplexus. We set out to test the hypothesis, suggested by previous observations of other frogs⁶, that females preferentially approach males that initiate bouts of calling.

Foster⁷ reported that certain males initiate more bouts than would be expected by chance, and numerous observations of our own verify this. For example, in a 1.5 h period, a group of approximately 20 frogs produced 10 bouts; one individual initiated seven of these, was second to begin calling in two, and third in one. It was not unusual for an individual to initiate bouts for several hours, and occasionally a frog would be a 'bout leader' for several consecutive nights.

We also discovered, by systematic field observations, that the calling of bout leaders differs in several other ways from that of other frogs⁸. We observed pairs of calling frogs, defining one frog of a pair as a bout leader if it initiated three consecutive bouts. Not only did the bout leaders initiate bouts of calling, but they were the last to stop calling when bouts ended ($P < 0.01$); they called at a faster rate during bouts ($P < 0.01$); they called louder ($P < 0.025$); and they were more likely to call during periods not defined as bouts ($P < 0.01$). Thus bout leaders call more actively than other frogs: they expend more energy on calling.

It is rare to see females selecting males in the field, but we observed three instances of this, and in each case the favoured frog was a bout leader of a group of at least five frogs. The probability of this occurring by chance is less than $(1/5)^3 = 0.008$.

We tested more rigorously the relative success of bout leaders and other males in a laboratory experiment. We did the experiment in a circular arena having four loudspeakers on the circumference (Fig. 1). A Uher 4000 Report-L tape recorder, wired to a stepping relay, played identical calls sequentially (corresponding to the antiphonal calling of real frogs) through the speakers. Each speaker called 30 times per min (approximately the same rate as the frog from which the calls were recorded). Bouts of calling were 2 min long, with 1 min lulls between. A randomly chosen speaker was the bout leader for each trial; for each bout it called three times before the other speakers were turned on (not an unusual number of times for a bout leader to call before other frogs join). We released the female from the cage in the centre of the arena about 15 s after the start of the fourth bout. If she moved, within 60 min, to within 2 cm horizontal distance of a speaker, we recorded a 'choice'.

One would expect, by chance alone, that one-quarter of the responding females would choose the bout leader. Of 18 females, however, 14 choose the bout leader ($P < 0.001$; binomial test). Our experiment shows therefore that females prefer bout leaders even when they give the same call as other chorus members. We do not know if the other be-

havioural differences between bout leaders and other frogs enhance this preference.

Since it is advantageous for a male to initiate bouts, why does the competition to do this not result in all males calling all the time? What limits males from calling more? Since calling involves repeated and, what seem to be very strong contractions of abdominal muscles⁹, we hypothesised that the length of a calling bout is limited by fatigue of these muscles. To test this hypothesis, we assayed

Table 1 ATP and lactate ($\mu\text{mol per g wet tissue}$) in frog calling muscles

Replicate	ATP		Lactate	
	Calling frog	Control	Calling frog	Control
1	1.75	3.05	0.83	0.51
2	2.97	2.90	Nil	2.13
3	2.85	2.74	0.63	3.10
4	Nil	Nil	0.91	4.41
5	Nil	4.41	0.42	0.42

ATP and lactate in the abdominal muscles, predicting lower ATP and higher lactate levels in frogs that had just finished a bout of calling compared with controls. We froze experimental animals in liquid nitrogen, cut off the abdominal muscles while still frozen, then extracted the metabolites and assayed them enzymatically by established procedures¹⁰⁻¹¹. The results (Table 1) show no significant differences between control and calling frogs. Thus they do not support the hypothesis that frogs stop calling because of muscular fatigue, and the question of why frogs do not call continuously remains unanswered.

Our study also raises several evolutionary questions. Why do females choose males that call most actively? Is it simply that these males are easiest to locate because they call during periods of little acoustical interference; or do they also make better mates? Since a male's sole investment in the offspring is sperm, we must ask if the sperm of bout leaders produces more or better offspring. Finally, accepting that the amount of calling a male can do is limited and that males compete to call during periods when few others are calling, why do they not develop other strategies of calling? Some males, for example, could rest during bouts, and then start calling when the other frogs stopped. The answer may be that it is advantageous to contribute to bouts, not only because it increases the overall intensity of calling and therefore may attract more females to the area, but also because, in doing so, a frog interferes acoustically with the calling of other individuals, reducing their chances of attracting females.

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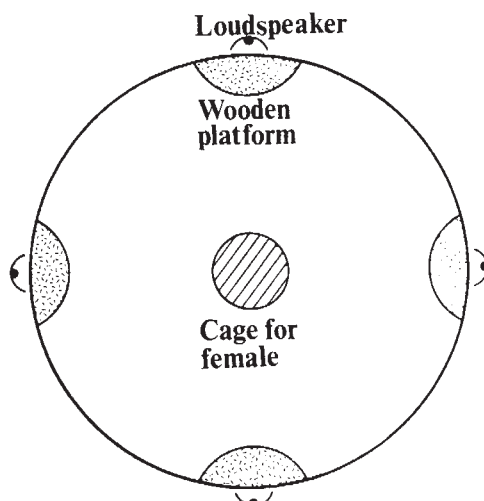
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Fig. 1 Top view of the arena (1 m diameter) used in the female choice experiment. The arena was filled with water (depth 10 cm), and the cage floor and the platforms were slightly submerged (0.5 cm).



Vertical clinging and leaping in a neotropical anthropoid

NAPIER and Walker¹ proposed a new category of primate locomotor behaviour which they called "vertical clinging and leaping". They believed that among living primates this category included only certain prosimians. It has since been recognised that non-prosimian primates (for example, *Saquinus*², *Cacajao*³, and *Callicebus*⁴) may at times also leap to and from postures in which the body is held vertically at rest. In a recent review of vertical clinging and leaping Stern and Oxnard suggest that "future behavioural observations will show that almost all primates may occasionally move in this way"⁵. In view of the acrobatic arboreal abilities of primates this would not seem remarkable, given appropriate environmental conditions and stimuli. So far, however, no one has reported any anthropoid primate engaging habitually in this form of positional⁶ behaviour.

From July to September, 1974, we observed a group of nine pygmy marmosets, *Cebuella pygmaea*, for over 200 h in inundatable forest at the edge of the Nanay river, about 30 km south-west of Iquitos, Peru. The group consisted of four adults, three subadults, and two infants carried by an adult male. (A comprehensive study of this group, including a detailed presentation of methods, is being prepared by M. Ramirez.) The vegetation was virgin tropical rain forest with a continuous canopy between roughly 10 and 20 m high, and a few emergent trees up to 35 m. Relatively heavy undergrowth existed below the canopy, including many bushes and lianas of varying size. The marmosets were normally awake for about 11.5 h each day, from 0615 to 1745. By quantifying frequency and duration of activity patterns for 4 d, we found that adult animals spend approximately 48% of their time feeding (including foraging for insects), 12% moving (exclusive of locomotion involved in feeding), and 40% resting (including grooming). We obtained the following data on adult animals while noting whether the substrate was more or less horizontal (less than 45° inclination) or vertical (greater than 45°). During 16 h observation of feeding behaviour, 77% of the animals' time was spent clinging to vertical supports of large diameter while feeding on sap. *Cebuella* used a wide range of locomotor behaviours, including quadrupedal walking and running along supports as well as leaping between supports. We observed leaps of up to 2 m which confirms the observations of Christen on captive *Cebuella*⁶. We observed and counted 288 leaps over several days and of these 38% were from one vertical support to another, 28% from a horizontal to a vertical, 19% from a vertical to a horizontal, and only 15% were from a horizontal to a horizontal. Thus, a total of 85% of all leaps observed were to and/or from a vertical supporting branch. Animals spent 57% of their resting time (48 h observation) clinging to vertical supports. The longest period during which an adult individual clung continuously to a vertical support without moving was 96 min; the longest period that an animal was observed sitting on a horizontal support was 16 min. We believe these data amply justify consideration of *Cebuella pygmaea* as a neotropical vertical climber and leaper.

Cebuella is a tiny animal, the smallest New World monkey and the second smallest primate; average weight of adults is 145 g (ref. 7). It spends most of its feeding time obtaining and eating sap, a behaviour which has also been noted for *Cebuella* in Columbia by Moynihan⁸. In addition *Cebuella* feeds on insects and berries. Insects and spiders are approached by slow stalking and are frequently captured using a rapid pouncing leap. Most insect foraging occurs in areas of entangled lianas and bushes below the level of the closed canopy (the primary foraging zone). This substrate,

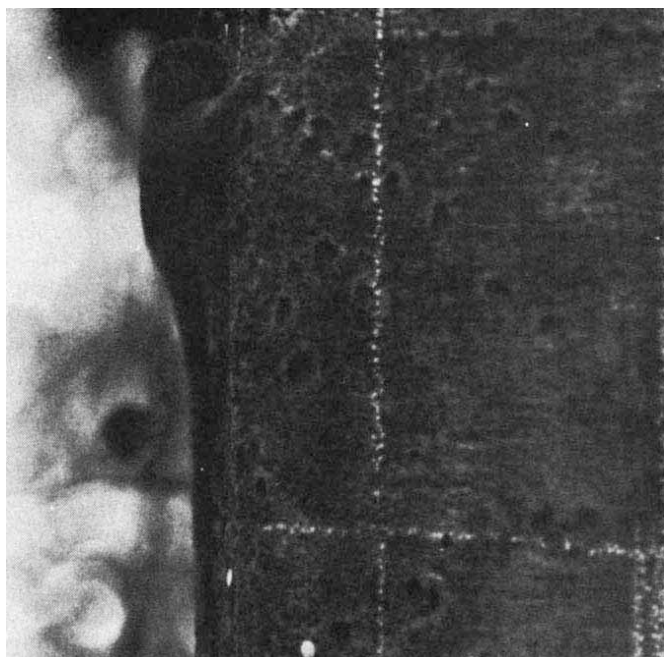


Fig. 1 Posture of adult *Cebuella* while feeding on sap of *Quararibea* sp. (Bombacaceae).

in contrast to the canopy, has a relatively high frequency of vertical supports. An individual may spend 85 to 90% of its total waking hours in the primary foraging zone. Berries ('renaco', *Ficus* sp., and 'caymittillo') are an infrequent source of food, and are procured from terminal branches in the canopy (that is, a secondary foraging zone), or from bushes below it.

In terms of time spent, sap was the most important food resource for *Cebuella* during our study. Sap was obtained from lianas and from the trunks of trees of both large and small diameter. *Cebuella* obtained this exudate by using its semiprocumbent lower incisor teeth to scrape fissures into the bark, primarily while clinging to large vertical tree trunks. The trunk diameter of the preferred sap-feeding tree (*Quararibea* sp., Bombacaceae) measured 51 cm at the feeding level. Adult individuals spent an average of 97 min each day preparing, and/or feeding at, sap-holes on this large tree alone. The sap of other large diameter trees, including *Palicourea macrobotrys* (Rubiaceae), was also used for feeding. Throughout these feeding bouts on large tree trunks a variety of clinging postures were used, with the body oriented upright, inclined, or head downward. In the latter posture the lower extremity was rotated laterally. In the upright position the base of the tail was often pressed to the tree trunk; the forelimbs were either abducted and fully extended (Fig. 1) or adducted at the shoulder and partially flexed at the elbow; the hindlimbs were widely abducted indicating great hip mobility, or closely adducted and flexed beneath the body. In all these postures the claws of *Cebuella* served a particularly important function specific to feeding. During scraping actions of the teeth against the bark, the manual claws anchored the forelimbs laterally, while the pedal claws anchored the hind limbs below (Fig. 1). The head (and often the shoulders) was fixed on the vertical column. The forelimbs acted as levers, flexing at the elbow and/or wrist, increasing the mechanical advantage at the mandibular incisors. Most important, during all postural behaviours on large substrates the claws seemed to be firmly embedded in the bark.

Napier and Walker¹, in recognising vertical clinging and leaping as a distinct locomotor category, suggested a fairly precise correlation between its behavioural and morphological features. Stern and Oxnard³ pointed out, however, that multivariate analyses of the various components of the

locomotor skeleton "suggest that there is more than one kind of morphology among vertical clingers and leapers and, therefore, that there is likely to be more than one kind of vertical clinging and leaping." They distinguished two such kinds, one for the indriids, and a second for *Microcebus*, *Galago*, and *Tarsius*; subsequently Oxnard¹⁰ suggested a third mode manifested by *Lepilemur*. Jouffroy and Gasc¹¹ distinguished the same three locomotor groups based on morphology presumed to be adapted specifically for leaping and not for clinging.

Our data indicate that claws in *Cebuella* are for clinging to large vertical supports, and are not part of a complex related to leaping. We do not yet know what is the adaptive relationship between leaping and vertical clinging; *Cebuella* does both.

In *Cebuella* vertical clinging involves grasping (of slender supports) with the hallux, but also involves clinging to broad supports with the claws of both hands and feet. As Cartmill has pointed out, clawed primates are generally more competent than clawless ones of similar body size in moving on thick vertical supports. Vertical positional behaviour offers the pygmy marmosets their only (or at least their most efficient) access to sap, an apparently essential food resource. Clinging is a postural not a locomotor adaptation. Failure to distinguish between posture and locomotion may overlook the biological importance¹² of clinging which in *Cebuella* is clearly related to feeding. Differing biological functions for vertical clinging have probably evolved in different primate lineages. Clinging and leaping faculties may or may not be part of the same form-function complex¹², the observed differences in morphology arising from this.

We conclude that in *Cebuella*, semiprocumbent mandibular incisors, small body size and clawed digits are part of an adaptive complex especially related to feeding on sap while clinging to large vertical supports. Similarly, *Galago elegantulus*¹³, *Phaner furcifer* and *Microcebus coquereli*¹⁴, of medium body size, with very procumbent mandibular incisors, and modified nails which function as claws, also feed on sap while clinging to large tree trunks¹⁵. Thus, there is an evolutionary convergence in biological importance (not in diagnostic vertical clinging and leaping morphology) of vertical clinging adaptations to exploit sap-feeding niches in certain medium-sized nocturnal galagines and cheirogaleines, and in the small diurnal *Cebuella pygmaea*.

This suggests that vertical clinging behaviours are postural adaptations, related to feeding and dependent on the size of the support and on the spatial location of the food resource. Leaping behaviours, on the other hand, are locomotor adaptations. Thus, they serve different biological functions which may or may not be related to obtaining food.

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Control of rust diseases by diterpenes from *Nicotiana glutinosa*

AN epimeric mixture of the diterpenes sclareol and 13-epi-sclareol (sclareol) (Fig. 1) has been shown to constitute 10% of the surface exudate on leaves of *Nicotiana glutinosa*¹. Investigations into its effect on fungal growth showed that it neither inhibits the spore germination of several species of facultative pathogens *in vitro* nor reduces the weight of mycelium produced in liquid medium. The development of hyphae of certain species of fungi, for example *Alternaria brassicicola*, is, however, markedly affected by this compound. In the presence of sclareol, increased branching is induced which leads to a substantial reduction in the diameter of colonies growing on agar¹. Such morphological effects could be interpreted as the result of alterations in the regulation of natural fungal growth processes. This report describes the effect of sclareol on the germination and growth of rust fungi *in vitro*, and the protection it can provide to plants against diseases caused by these fungi.

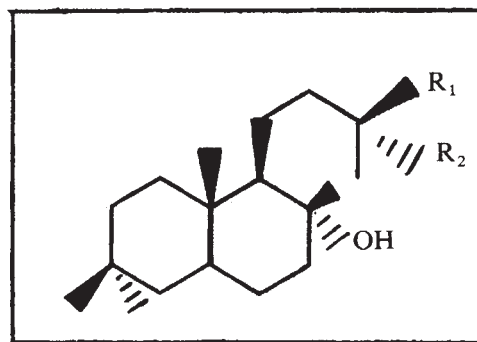


Fig. 1 Sclareol: an epimeric mixture of sclareol ($R_1 = \text{OH}$; $R_2 = \text{Me}$) and 13-epi-sclareol ($R_1 = \text{Me}$; $R_2 = \text{OH}$).

The germination of rust uredospores was assessed in the well slide test² and on the surface of impregnated agar. In slide tests, French bean rust, *Uromyces appendiculatus*, was completely inhibited by $25 \mu\text{g ml}^{-1}$ sclareol ($8.3 \times 10^{-5} \text{ M}$) and its germ tubes were very much shortened at $5 \mu\text{g ml}^{-1}$. In the presence of sclareol, broad bean rust (*U. viciae-fabae*) produced small protuberances at the surface of the uredospores and normal growth of the germ tube occurred only at levels below $25 \mu\text{g ml}^{-1}$. The results with *Puccinia recondita* f. sp. *tritici* (wheat leaf rust) were more variable, but again normal growth of the germ tube occurred only if the concentration of sclareol was below $25 \mu\text{g ml}^{-1}$ (Table 1). Similar results were obtained using impregnated agar.

Protective fungicidal effects were measured by spraying sclareol, dissolved in a 50% v/v acetone-water mixture, on to leaves to the run-off point before inoculation³. In replicate experiments, applications of $100 \mu\text{g ml}^{-1}$ sclareol consistently gave good control of rust on French bean, broad bean and wheat, reducing infection to less than 10% of control. Thus sclareol, a natural component from the leaves of *N. glutinosa*, can be used to protect other plants from disease.

Table 1 Effect of sclareol on the germination and growth of rust uredospores

Concentration of sclareol ($\mu\text{g ml}^{-1}$)	Test no.	<i>U. appendiculatus</i>	<i>U. viciae-fabae</i>	<i>P. recondita</i>
5	1	35 (20)	100 (100)	76 (100)
	2	32 (33)	100 (100)	80 (100)
10	1	28 (20)	94 (100)	45 (60)
	2	23 (33)	100 (50)	60 (100)
25	1	0 (0)	81 (8†)	36 (20)
	2	0 (0)	26 (25)	16 (100)
50	1	0 (0)	0 (†)	37 (20)
	2	0 (0)	0 (25)	20 (100)
100	1	0 (0)	0 (†)	23 (10)
	2	0 (0)	0 (†)	16 (60)
250	1	0 (0)	0 (†)	13 (20)
	2	0 (0)	0 (†)	16 (60)
500	1	0 (0)	0 (†)	16 (10)
	2	0 (0)	0 (0)	23 (60)
1,000	1	0 (0)	0 (†)	27 (10)
	2	0 (0)	0 (0)	27 (60)
	1*	60 (400 μm)	96 (480 μm)	92 (400 μm)
	2*	94 (240 μm)	62 (160 μm)	75 (400 μm)

Figures are the germination and (in parentheses) mean germ tube length obtained in two separate slide tests, both values expressed as percentage control.

*In the absence of sclareol, the percentage germination and length (μm) of the germ tube were as shown.

†Small protuberances present.

‡Germ tubes swollen and distorted.

In subsequent experiments sclareol levels up to 500 $\mu\text{g ml}^{-1}$ failed to control powdery mildew on cucumber or wheat, anthracnose on cucumber or chocolate spot on broad bean. It is clear that as a protectant, sclareol is highly specific for rust fungi and that its capacity to control fungal disease is closely correlated with the effects it produces *in vitro*. Thus an examination of the surface of broad bean leaves, which had been sprayed with 100 $\mu\text{g ml}^{-1}$ sclareol and inoculated with rust, showed that, whereas germination of the rust spores was almost completely inhibited, spores of epiphytic fungi were germinating normally. This specific toxicity towards rust fungi may arise as an extreme expression of the suppression of hyphal extension noted with other fungi¹, since rust fungi growing *in vitro* or on the leaf surface are normally devoid of lateral hyphal branches³.

Little is known about the physiological mechanisms controlling fungal growth or about the endogenous compounds which may regulate such growth processes as hyphal branching, appressorium formation or haustorium formation. This situation contrasts markedly with knowledge of higher plant growth regulation—fully exploited for the development of selective hormone-type herbicides and of growth retardants, which interfere with the action of plant growth regulating hormones⁴.

The present results, however, indicate that a study of endogenous fungal growth regulators and of compounds, such as sclareol and griseofulvin⁵, which may mimic their action, offers an approach that could prove rewarding in research on the selective control of plant disease.

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Inhibition of pulmonary tumour development in rats sensitised to rat embryonic tissue

PREVIOUS investigations have established the presence of tumour-associated embryonic antigen(s) at the cell surface of virus-induced, chemically-induced and spontaneously arising tumours^{1–4}. *In vitro* tests have shown that rat tumour cells, expressing the embryonic components, act as appropriate targets in cytotoxicity assays using lymph node cells from animals sensitised to embryonic tissue^{3,5} (L.P.S., R.C.R. and R.W.B., unpublished). In these tests lymph node cells, from either multiparous rats or rats immunised against embryonic tissue, either by inoculation of irradiated 14–15-d-old rat embryo cells or embryonic excision, were shown to be cytotoxic for a large range of experimental rat tumours. Translation of these studies to the *in vivo* situation has not been uniformly successful in all the tumour systems studied. Some investigators have shown that embryo immunisation can induce immunity to subcutaneous challenge with minimal doses of tumour cells^{6,7}. Conversely other laboratories, using similar immunisation procedures and tumour models have been unable to confirm these observations (refs 8–10 and L.P.S., R.C.R. and R.W.B., unpublished). It has previously been established that intravenous inoculation of rat tumour cells leads to the development of pulmonary tumour growth^{11,12}. Studies were therefore initiated to investigate whether or not presensitisation of rats to rat embryonic tissue could prevent the growth of tumours in the lungs. The results presented here show positive reductions in pulmonary tumours in rats sensitised to embryonic tissue compared with untreated controls.

The tumours used in the present study have previously been shown to produce lung nodules following intravenous inoculation of single tumour cell suspensions^{11,12}. Epithelioma Spl arose spontaneously in a female rat from our own inbred colony, and sarcoma Mc7 was induced by subcutaneous inoculation of 3-methylcholanthrene. The tumours were maintained by serial transplantation into rats of the same sex. Single tumour cell suspensions were prepared by trypsin digestion, washed in Hanks' BSS and resuspended in Hanks' BSS at a concentration of 5×10^6 cells ml^{-1} .

Groups of rats were immunised with three weekly inoculations of irradiated (5,000 rad) 14–15-d-old rat embryo cells

Table 1 Incidence and number of pulmonary tumour nodules in Wistar rats sensitised against syngeneic rat embryonic tissue and challenged intravenously with a methylcholanthrene-induced rat sarcoma (Mc7) or a spontaneously arising epithelioma (Spl)

Test	Immunisation procedure	Tumour cells	No. of rats with pulmonary nodules	No. of pulmonary nodules	P
1	Nil	Sarcoma Mc7*	4/5	0, 7, 9, 9, 17	
	Irradiated rat embryo cells ($\times 3$)		2/4	0, 0, 1, 1	<0.02
2	Nil	Sarcoma Mc7*	3/4	0, 17, 181, 300+	
	Embryoma excision		1/4	0, 0, 0, 3	<0.04
3	Nil	Sarcoma Mc7†	4/4	7, 12, 22, 36	
	Multiparous female rats		2/5	0, 0, 0, 1, 1	<0.004
4	Nil	Epithelioma Spl*	4/5	0, 2, 7, 8, 10	
	Irradiated rat embryo cells ($\times 3$)		5/5	1, 2, 2, 3, 4	<0.3
5	Nil	Epithelioma Spl†	4/4	7, 9, 11, 11	
	Multiparous female rats		1/4	0, 0, 0, 3	<0.004

*Rats challenged with 1×10^6 tumour cells (0.2 ml volume) intravenously 7–10 d following the third immunisation or after surgical excision of a developing embryoma.

†Multiparous female rats having had three or more litters were challenged intravenously with 1×10^6 tumour cells (0.2 ml volume) within 4 weeks following the last pregnancy.

(L.P.S., R.C.R. and R.W.B., unpublished). Rats were inoculated with 2×10^6 (0.2 ml volume) rat embryo cells subcutaneously and 1×10^6 cells (0.1 ml volume) intraperitoneally. Seven to ten days after the final inoculation both treated and control rats were inoculated intravenously with 1×10^6 tumour cells (0.2 ml volume). Multiparous rats having had three or more pregnancies, and rats grafted with 14–15-d-old rat embryo tissue and the embryoma excised when 1–2 cm in diameter, were similarly inoculated intravenously with sarcoma Mc7 or epithelioma Spl cells. Experiments were terminated 4 to 6 weeks after tumour cell inoculation and the lungs examined for pulmonary tumours as previously described¹³. The significance of the results was analysed by the Wilcoxon non-parametric rank test.

Using sarcoma Mc7 cells, significantly fewer tumour nodules developed in the lungs of rats immunised against 14–15-d-old rat embryo tissue, by either inoculations of irradiated rat embryo cells or by embryoma excision, compared with control rats (Table 1, experiments 1 and 2). Similarly, multiparous rats also developed significantly fewer lung tumours than nulliparous controls (Table 1, experiment 3). A reduction in lung tumours was also observed in rats sensitised to embryonic tissue and challenged intravenously with epithelioma Spl cells (Table 1, experiments 4 and 5), although these results were shown only to be statistically significant in experiments using multiparous rats challenged with Spl cells. In all experiments shown in Table 1 the size of lung nodules detected in embryo-immune rats was considerably less than those seen in control animals.

Previous studies from this laboratory have shown that inbred Wistar rats sensitised to embryonic tissue do not consistently reject a subcutaneous challenge with syngeneic tumour cells derived from either chemically-induced or spontaneously arising rat tumours (ref. 8 and L.P.S., R.C.R. and R.W.B., unpublished), and conflict with reports from other laboratories using similar tumour systems and immunisation procedures^{7,14,15}. Lymph node cells and spleen cells prepared from multiparous pregnant rats or rats immunised with embryonic tissue do, however, demonstrate cytotoxicity *in vitro* for target 14–15-d-old rat embryo cells and tumour cells^{5,16} (L.P.S., R.C.R. and R.W.B., unpublished). Various theories can be proposed as to why embryo-immune rats do not reject *in vivo* challenge with tumour cells expressing embryonic antigens at their cell surface, thus allowing immunological recognition and destruction *in vitro*. First, the nature of embryonic antigen expression may vary depending on conditions, and in the *in vivo* situation may assist in making the embryonic antigen component an inappropriate target for rejection to occur. Alternatively the nature of the immune response of the host to embryonic antigens may not be sufficient to

facilitate a rejection response, and there is evidence to suggest that the cellular immune response to tumour-associated embryonic antigens is effected by a different immunological mechanism from that operative towards the tumour-specific component (J. Bray, R.C.R., R. A. Robins and R.W.B., unpublished).

The results presented here show that embryo-immune rats are capable of limiting the growth of tumours in the lungs. Thus, intravenous inoculation of tumour cells may facilitate direct contact with cytotoxic effector mechanisms early on, and so prevent the establishment of the tumour. On the other hand (or in addition), tumour cells may be unable to lodge in the lungs because of mechanisms other than those of an immunological nature. Studies are in progress to determine whether inhibition of pulmonary tumour growth is caused by a specific immunological response to the antigens present on 14–15-d-old rat embryo and rat tumour cells.

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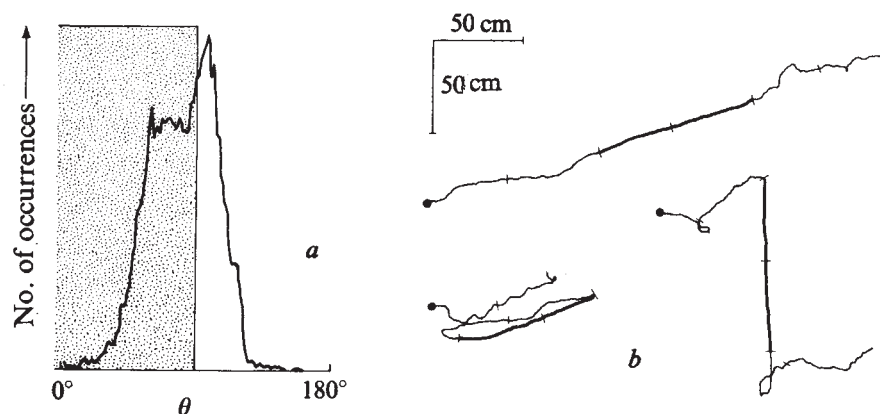
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Stationary and dynamic responses during visual edge fixation by walking insects

IF the visual surround of a walking animal is rotated, the animal turns in a characteristic way. With arthropods, this optomotor (optokinetic) response has usually been described in terms of the angular velocity of the body or eyestalks. The difference between these velocities—the slip speed—has been considered as the necessary visual stimulus. Most of the

previous investigations of this feedback system have been carried out in open loop conditions¹. Special care was taken that the head of the tethered animal was not free to move. In this investigation, free moving animals with head movements unrestricted also show optomotor responses when no slip speed between animal and surround is present. An explanation is offered which is in accordance with investigations on the housefly, *Musca domestica*^{2,3}.

In the experiments the mealworm beetle, *Tenebrio molitor*, walks freely on the vertex of a dark grey sphere (80 mm in diameter) which is servo-controlled to eliminate displacement (but not rotation) of the beetle with respect to the vertical axis of a surrounding rotatable cylinder (100 mm high and 94 mm in diameter), carrying the visual panorama on its inner surface. The animal carries on the thorax a small disk of highly reflecting foil, which is imaged in infrared light on the centre of a photodiode device with independent quadrants. The photocurrents control two servomotors, which rotate the ball to cancel translation of the beetle. Because the animal ordinarily walks with its body axis at a tangent to its track, one can derive two voltages, U_θ and U_v , proportional to angular direction θ and linear velocity v , respectively.



Sixteen small light bulbs, arranged symmetrically above a screen of translucent white paper, provide an adequately uniform illumination of the visual panorama, which subtends an angular altitude from 26° below to 59° above the horizontal plane of the animal.

Figure 1 illustrates the walking behaviour measured with stationary panoramas. In Fig. 1a the response edge fixation is shown: a histogram of samples of the direction of movement over a 2 min period (U_θ sampled every 5 ms). Here the panorama was a half-white, half-black surround; on average, the beetle walked towards the right edge of the black field.

Figure 1b demonstrates that the walking direction is visually guided. Here the panorama was a single black stripe subtending 22.5° in azimuth. The tracks of the beetle are reconstructed by integrating the voltages proportional to the velocity components v_x and v_y and plotting them against one another on an x - y recorder. The beetle ran for 1 min in the dark (thin lines); the lights were then turned on for 1 min (heavy lines) and finally off again for a further minute (thin lines).

In the dark, even though the track is somewhat tortuous, a certain average direction is maintained. On illumination, direction alters immediately towards that of the black stripe and the track becomes straighter. If the dark direction happens to correspond to that of the stripe, as in the upper track, direction is unchanged. Surprisingly, the initial direction in the dark is resumed when the lights are turned off. Although it has not been excluded that this behaviour depends on a clue within the experimental arrangement, similar phenomena have been observed with the millipede, *Schizophyllum sabulosum*⁴.

When the drum is rotated, the beetle tries to maintain fixation of the black stripe. At moderate angular velocities it succeeds

(Fig. 2a). The average angular velocity of the animal during this dynamic fixation is identical to the angular velocity of the drum. With increasing drum velocities, however, the animal lags more and more behind the stripe, suddenly makes a fast turn against the direction of the drum's movement, locks on to the next stripe behind and fixates again for a while (Fig. 2b). The duration of these fixation periods becomes shorter and shorter as the angular velocity of the drum is further increased.

If the panorama consists of several black and white stripes of equal width, at moderate drum velocities the beetle fixates one of the black stripes for long periods of time; occasionally it switches to a different stripe. Usually the change is to a stripe following the one previously fixated, but in some cases (Fig. 2c) the beetle overtakes the drum; there it switched from black stripe No. 1 to black stripe No. 3. The net result of these small but frequent backward jumps is that the average angular velocity of the animal is less than that of the drum.

Open loop investigations¹ suggest that the direction and the magnitude of the optomotor response should not change if the panorama is rotated with constant angular velocity. Furthermore, it has been concluded that the difference between the angular velocities of the panorama and the animal is the

Fig. 1 a, Angular distribution of the direction of movement of a mealworm beetle during a 2 min period of walking, sampled every 5 ms. The shaded bar represents the black half of the visual panorama; the object of fixation is the vertical border separating it from the white half. b, Tracks of three beetles, in the dark (thin lines) and during illumination (heavy lines); a single black stripe subtending 22.5° in azimuth was presented in different angular positions. ●, Starting points; cross bars, 0.5 min time intervals.

necessary stimulus for the response; the two velocities should never⁵, or only at their lowest values⁶, be equal. The image of the surround would therefore be expected to be continuously displaced with respect to the retina.

My findings do not confirm these expectations, but the contradiction can probably be resolved. Fixing the head of the tethered animal to the thorax allows the precise control of the relative angular velocity between the eyes and the panorama but also prevents scanning movements of the head. It has been shown, however, that in stationary illumination conditions in the housefly, at least a random relative movement—instead of an unidirectional slip speed—between the eyes and the panorama is both necessary and sufficient to elicit fixation reactions such as those shown in Fig. 1. Since such scanning movements were not suppressed in the present investigations, it is suggested that the turning response of the animal shown in Fig. 2a-c can be accounted for as fixation of moving edges rather than as velocity compensation.

Equation (1) has been adapted from Reichardt² to describe fixation response:

$$d^2\theta/dt^2 + a(d\theta/dt) = ky(\gamma - \theta) \quad (1)$$

where γ is the angular position of a fixated edge, θ the direction of the body axis and a and k are constants. The function y , which depends only on the deviation $\delta = \gamma - \theta$ between the angular direction of the fixated edge and that of the body axis of the animal, describes the attractive force an edge exerts on the animal. Since this function has not yet been determined quantitatively for *Tenebrio*, it was arbitrarily chosen as shown in the inset of Fig. 2d. Analog computer solutions of equation

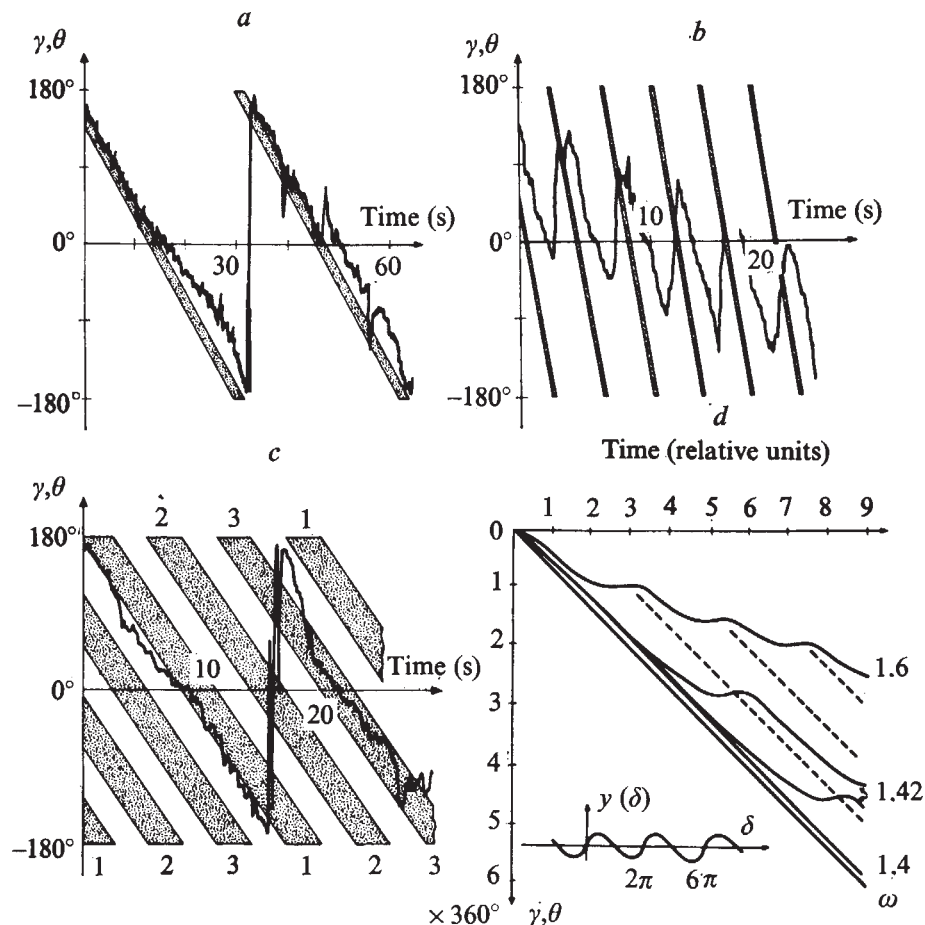


Fig. 2 *a-c*, Dynamic fixation of rotating patterns. The angular position γ of the rotating pattern (counter-clockwise, constant angular velocity) and the angular position θ of the walking beetle are shown against time. *a* and *b*, One 22.5° black stripe as in Fig. 1*b*; *c*, three 60° stripes. Angular values outside the range $\pm \pi$ rad are shifted by $n2\pi$ to the range of the plots. *d*, Analog computer simulation of the fixation response as described in the text. The waveforms for successive cycles have not been shifted to a single range of 2π rad.

(1) for $\gamma = \omega t$, where ω is the angular velocity of a single fixated edge, are shown in Fig. 2*d*.

As in my experiments, the angular position θ of the body axis deviates at moderate velocities ($\omega = 1.4$ relative units), lagging by a small constant amount behind the angular position γ of the fixated edge, whereas the two angular velocities are identical. At a critical value (here, $\omega = 1.42$) occasional jumps, and at still higher values ($\omega = 1.6$) frequent and regular jumps, of magnitude $\theta = 2\pi$ occur; each jump is followed by a period of dynamic fixation. The frequency of occurrence of such jumps, at a given drum velocity, depends on both $\gamma(\delta)$ and the parameters of equation (1). As a result of computer noise the jumps near the critical value of ω occur at irregular intervals. If the panorama contains more than one edge, the jumps occur at the respective neighbouring edge in less than 2π steps, as also observed in my experiments.

The qualitative properties of the theoretically derived curves agree well with those of the beetle's response. This does not exclude the possibility that the optokinetic reaction is important in the turning response of the animal. At higher drum velocities or increased number of stripes (see Fig. 2*b* and *c*) the backward jumps give rise to an unidirectional slip speed on the average. This in turn can elicit an optokinetic reaction in the sense of a velocity compensation, which is added to the fixation response.

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Effect of experimental cerebral infarction in rat brain on catecholamines and behaviour

ALTHOUGH cerebral vascular accident or stroke is a frequent clinical problem, there has been little systematic research into the cause of the common behavioural consequences such as emotional lability, depression and motor and cognitive deficits. Ischaemic brain injury affects the content and metabolism of brain catecholamines in rats¹, monkeys and gerbils², as well as the concentration of monoamines in human cerebrospinal fluid³. In an attempt to study experimental stroke, we have occluded surgically the middle cerebral artery in rats and found, during the 40-d postoperative period, changes in both behaviour and brain catecholamines.

Sprague-Dawley male rats (150-200 g) were housed individually in a 12 h light and 12 h dark environment and given rat chow and water *ad libitum*. In one group of 30 rats, the right middle cerebral artery was ligatured with 6-0 suture just above the rhinal fissure, and severed distal to the ligature. In a second group of 25 sham-operated rats the artery was exposed, but not ligatured. The ligature procedure causes no postoperative mortality and the lesion always destroys only cortical tissue in the lateral aspect of the fronto-parietal cortex, above the rhinal fissure and far lateral to the cingulum bundle. The lesion extends through the entire depth of the cortex in most animals but in a few affects only the upper 60-75%. Even when the lesion extends through the entire depth of the cortex, however, there is no histological or fluorescence histochemical evidence of subcortical tissue damage. From above, the lesion

Table 1 Catecholamine concentrations after vascular lesion

	Days after vascular lesion	NA concentration			DA concentration		
		5	20	40	5	20	40
Lesioned parietal cortex	Concentration	276±29	425±39	447±46	153±39	192±30	224±57
	% Change	-36%†	-28%‡	-24%*	0%	+25%	+7%
Contralateral parietal cortex	Concentration	356±31	484±21	560±28	138±32	192±51	239±74
	% Change	-17%	-18%	-5%	-10%	+25%	+14%
Ipsilateral posterior cortex	Concentration	182±19	340±47	368±55	41±6	131±33	94±8
	% Change	-45%‡	-30%*	-24%	-59%*	+30%	-43%
Contralateral posterior cortex	Concentration	233±40	425±18	417±43	55±9	125±16	139±46
	% Change	-29%	-13%	-14%	-46%	+24%	-17%
Ipsilateral brainstem	Concentration	720±28	782±58	784±70	260±25	260±44	129±13
	% Change	-34%§	-29%‡	-29%§	-31%†	-31%	-53%‡
Contralateral brainstem	Concentration	775±24	1055±45	1091±62	307±40	327±20	233±36
	% Change	-29%*	-4%	-1%	-19%	-14%	-14%
No. lesioned		10	9	7	10	9	7
No. sham-lesioned		6	7	7	8	7	7

Catecholamine (CA) concentrations are expressed as ng g⁻¹ wet tissue weight ($\pm$ s.e.m.). Below each CA value is the percentage change as compared with sham-operated controls. Changes in control CA levels seemed to be the result of normal progressive development of monoamine innervation in these animals which were 45-d-old at the beginning of the study (29, 30). The NA changes were: 429±31 to 589±32 in parietal cortex; 330±26 to 486±38 in posterior cortex and 1,084±70 to 1,098±54 in brainstem, all changes occurred between 5 and 20 d after sham operation. The DA changes were: 154±15 to 210±35 in parietal cortex; 101±13 to 166±32 in posterior cortex; and 379±22 to 272±39 in brainstem, all changes occurred between 20 and 40 d after sham operation.

* $P<0.05$, † $P<0.01$, ‡ $P<0.005$, § $P<0.001$, catecholamine concentrations were compared with those of sham-operated controls, using Student's *t* test.

is circular and varies from 2 to 5 mm in diameter. Its location also varies depending on the distribution of the middle cerebral artery and the site of ligature (Fig. 1; inset). After the surgical procedure, one group of rats was subjected to performance tests while a second group was monitored for food intake. At 5, 20 and 40 d after the operation, groups of rats were killed and their brains were removed, dissected immediately and frozen for assay.

Six brain regions were analysed by a modification⁴ of the radioenzyme assay⁵ that determines picogram amounts of both noradrenaline (NA) and dopamine (DA) in tissue samples as small as 2 mg wet weight. Table 1 shows that in each region there was a unique pattern of change. In the cortex, the greatest deficits in NA occurred 5 d after operation; at 20 and 40 d NA levels approached or reached control values. This was also true of contralateral brain stem which was the only contralateral region to change significantly. The NA in the ipsilateral brain stem, however, remained 30% below control levels throughout the postoperative period. Brain DA did not change significantly except in the ipsilateral brain stem where concentrations decreased progressively, and in the posterior ipsilateral cortex where concentrations had decreased by 5 d after operation.

We measured spontaneous horizontal and vertical activity in a photocell chamber during 24 h, after 1 h of habituation. The average hourly spontaneous horizontal activity of the lesioned rats was significantly greater than that of controls from 2 to 20 d after the operation (Fig. 1). In contrast, spontaneous vertical activity of the two groups did not differ significantly throughout this period. Open-field observations revealed a left-sided forepaw weakness and decreased response to touch and pain for several hours after vascular occlusion. By 24 h, there were no grossly detectable motor or sensory deficits. Within each group, rats were paired before operation and tested in a standard shock box for shock-induced aggression⁶. Two independent observers rated responses either aggressive or non-aggressive (inter-rater correlation $r=0.96$, $P<0.001$). The shock threshold required to elicit vocalisation did not change after operation. The percentage of aggressive responses was greater in lesioned animals 2 d after operation compared with controls; however, from 15 to 30 d after the operation the percentage of aggressive responses in the lesioned rats was well below control levels (Fig. 1). Daily measurement of the amount of rat chow eaten (minus crumb spillage)

and of body weight revealed no significant differences between lesioned, sham-operated or unoperated control animals (Fig. 1).

The fact that the pattern of behavioural changes after vascular lesion differed for each behaviour studied, suggests that occlusion of the middle cerebral artery affects only certain behaviours and does not have a generalised nonspecific action. Although these lesioned rats may have some motor-sensory deficit not detectable by open-field observation or response to touch, there is evidence that the behavioural changes were not entirely attributable to such deficits. First, non-stereotyped hyperactivity is scarcely what one would expect from a hemiparetic or hemianalgesic animal. Second, an animal with bucco-lingual paresis or impaired taste or smell would not be expected to eat normally. Finally, the response to shock induced aggression was biphasic in the lesioned animals while there was no change in their shock threshold for vocalisation.

The nucleus locus coeruleus is the cellular origin for cortical NA fibres which project to wide area of the cortex including a component to the contralateral side (refs 7-9 and R. Freedman, S. Foote and F.E.B. in preparation). The origin of the widespread DA cortical fibres^{10,11} has not been determined. Electrolytic lesions of catecholaminergic fibres in the central nervous system result in changes of catecholamine syntheses or storage capacity in cell bodies proximal to the lesion^{12,13}, in distal terminal sites^{14,16}, and in regions remote from the lesion¹⁷. Thus, the initial decrease in catecholamine could result from release of local neuronal catecholamines following interruption of fibre pathways leading from brain stem to cortex.

The return of catecholamines to control levels by 20 or 40 d after operation may result from several mechanisms. For example, the changes in NA and DA we observed in the brainstem after cortical injury could represent altered metabolism which the perikarya of catecholaminergic neurones would be expected to show as the result of a shift in synthesis from catecholamines to material for axonal sprouting^{17,20,24}. Alternatively, the return to control levels in cortical regions after lesioning could represent increased formation of catecholamines in existing terminals. Finally, the failure of catecholamine in some areas to return to control levels may represent some arrested development of neurones. Quantitative recovery of the behavioural indices, occurring over the same time, may similarly be the result of any one of several neural pro-

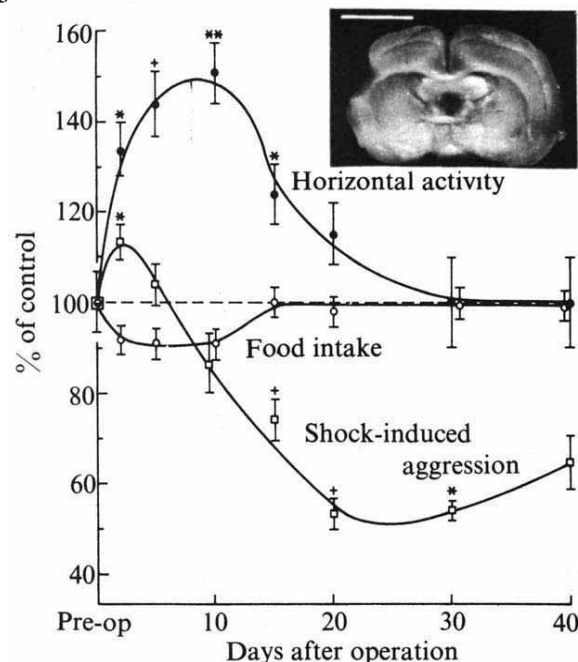


Fig. 1 Behavioural measurements after occlusion of right middle cerebral artery expressed as percentage of control. Spontaneous horizontal activity (●) is expressed as average hourly activity over 24 h. Preoperative level for both lesioned and sham-operated animals was 134 counts per hour. Chamber size was 40 × 32 × 35 cm with photocells 3 cm apart. Food intake (○) was measured in grams of standard dry rat chow consumed over 24 h with *ad libitum* feeding. Preoperative values for all animals were 22.4 g d⁻¹. Shock-induced aggression (□) was determined by subtracting the number of preoperative aggressive responses from the postoperative level. The change in the number of aggressive responses for a pair of lesioned animals was then compared with the change in the number of aggressive responses for a pair of sham-operated controls of the same postoperative interval. Shock given was 2 mA, r.m.s., scrambled shock, 0.5 s duration, 10 s intershock interval, total of 50 shocks. Bars indicate s.e.m. All values were compared with appropriate sham-operated controls using Student's *t* test; * *P* < 0.05; + *P* < 0.01; ** *P* < 0.001. Inset: coronal cross section of rat brain 40 d after ligation of right middle cerebral artery. Note that lesion involves only the lateral aspect of the parietal cortex with no injury to the underlying caudate. Bar indicates 5 mm.

cesses. By 20 d after lesioning, histochemical fluorescence reveals a return of cortical fluorescence and evidence of growth of the spinous process normally found on somata in the locus coeruleus (ref. 25 and R. G. R., F. E. B. and E. Battenberg, in preparation). This supports speculation that the response of catecholamine neurones to injury may influence the pattern of biochemical and behavioural changes after operation. Stroke is associated with emotional changes in many patients^{26,27}. In fact, epidemiological data suggest that stroke may play a role in the onset of endogenous depression in 10% of elderly patients²⁸. Furthermore, decreased catecholamine concentrations have been implicated in the aetiology of numerous abnormal emotional changes including endogenous depression^{31,32}. Although there are difficulties in drawing conclusions about humans based on animal experiments, we, nevertheless, believe this study provides evidence that the response of catecholamine neurones to vascular injury may cause the emotional changes seen after stroke and suggests the applicability of pharmacological treatments for these changes.

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Axonal degeneration associated with a defective blood-brain barrier in cerebral implants

THE capillaries in the central nervous system (CNS) are unique with respect to their barrier mechanisms, preventing to a varying degree many types of substances from passing into the brain parenchyma from the blood. Such barriers exist also against the catecholamines and their immediate precursor, L-dopa¹⁻³. As the blood-brain barriers serve to protect the central nervous elements against harmful substances in the circulation, it can be postulated that damage to or defects in the barriers could lead not only to functional disturbances but perhaps also to direct structural damage in the brain tissue.

We have found that cerebral implants of peripheral tissue become efficiently reinnervated by regenerating sprouts from lesioned central noradrenergic neurones⁴⁻⁶. Although the regenerated central fibres form functional connections in the transplant⁵, however, and although the transplants survive well in part, the central fibres in many transplants later develop fluorescence histochemical signs of damage, resulting in a progressive terminal degeneration of sometimes the entire terminal network⁶. In contrast, such changes were not noted in the intracerebral portions of the same neurones.

We now report that these degenerative phenomena are associated with a failure of the blood-brain barrier to develop in the new circulation of the cerebral implant, suggesting that the central axons are insufficiently protected in the transplanted peripheral tissue. Our study has focused on the development of two of the characteristic barrier properties in the newly-forming capillaries: the enzymic trapping mechanism for L-dopa, and the barrier for catecholamines. For comparison the same problem was investigated in transplants of CNS tissue to the anterior chamber of the eye, a situation in which the CNS tissue is revascularised from peripheral vessels.

Sixty female Sprague-Dawley rats (170-200 g body weight at the time of surgery) were used. Two types of transplantations were made in aseptic conditions and using barbiturate anaesthesia (Brietal, Lilly, 40 mg kg⁻¹ intraperitoneally): (1) autologous transplantations of irises to the caudal diencephalon, as described previously^{4,6} (these animals were killed at 3, 5, 14, 30, and 60 d after operation (three to six animals in each group)); (2) homologous transplantations of embryonic CNS tissue to the anterior chamber of the eye (small pieces (about 1 mm³) of the

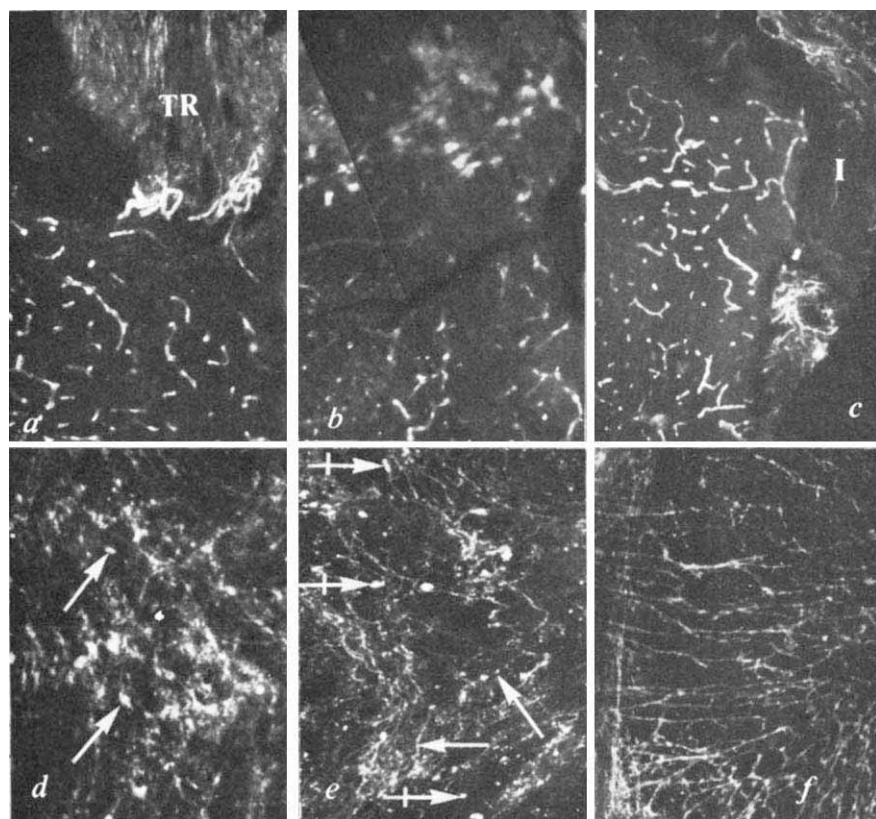


Fig. 1a. Ventral part of a 1-month-old iris transplant (TR) to the caudal diencephalon ($\times 88$). The animal was treated with nialamide and L-dopa before being killed (see text). At the zone of transition between the ventral tip of the transplant and the parenchyma containing normally fluorescent capillaries, ample intensely fluorescent tortuous capillaries occur, none of which retains its fluorescence when entering the transplant. *b* and *c*, Embryonic CNS tissue from the locus coeruleus region transplanted to the anterior eye chamber ($\times 88$). Nialamide and L-dopa treatment as in (*a*). *b*, 10 d survival. Normal or almost normal fluorescent capillaries are seen in the parenchyma. Fluorescent catecholamine cell bodies are seen in a cluster near the top of the picture. *c*, 30 d survival. Strongly fluorescent capillaries are seen all over the parenchyma up to the zone of transition between the CNS tissue and the iris (I), supplied with fluorescent noradrenergic sympathetic fibres. *d* and *e*, Comparison between disintegrating regenerated central noradrenergic fibres in whole mount diencephalic iris implants. *d*, Transplant from an animal treated intravenously with 6-OHDA (75 mg kg^{-1} , three injections at day 7, 14, and 21; 29 d survival ($\times 100$). Site of ingrowth in the dilator of fibres showing characteristic signs of axonal damage. The fibres are distorted and swollen and several distended axon stumps are seen (arrows). *e*, Regenerated central terminal noradrenergic plexus in the dilator under spontaneous resorption in a 2-month-old diencephalic iris implant ($\times 113$). Arrows show axons in various stages of disintegration, and crossed arrows denote distended axon stumps. *f*, Whole mount iris transplant from caudal diencephalon (1 month survival; $\times 113$) Ciliary region to the left in the picture. Adjacent dilator area, comparable to that in (*e*), shows a principally normal noradrenergic ground plexus without signs of degeneration.

brain stem were taken from embryos with a crown-rump length of 15–30 mm, and placed in the anterior eye chamber of the adult recipient rats^{7,8}; these animals were killed after 5, 10, and 30 d (five to ten animals in each group)).

All transplanted animals, except those treated with 6-hydroxydopamine (6-OHDA), were given nialamide (Niamid, Pfizer, 100 mg kg^{-1} intraperitoneally) and 1 h later L-dopa (50 mg kg^{-1} intraperitoneally), and were killed by decapitation 20 min after the last injection. From the brains, the iris transplants were either processed as whole mounts (3–14 d specimens), or dissected out together with surrounding brain tissue (30–60-d specimens) and freeze-dried. From the eyes, the irises with attached CNS transplants were dissected out and freeze-dried. Fifteen of the animals bearing ocular CNS implants were perfused with Indian ink by way of the ascending aorta immediately before being killed. All specimens were processed for fluorescence histochemistry according to the Falck-Hillarp formaldehyde method⁹.

In one set of experiments (10 animals) the ability of 6-OHDA to pass into the cerebral iris implants was tested. Half of them were given a single injection of 75 mg kg^{-1} 6-OHDA intravenously 1 month after transplantation and killed 3 d later. The others were given three injections of 6-OHDA (75 mg kg^{-1} intravenously) 7, 15, and 21 d after surgery, and were killed on day 29. The iris transplants were processed as whole mounts for fluorescence microscopy as above. A further two animals were perfused at 6 weeks after transplantation with trypan blue (10 ml by way of the ascending aorta) immediately before being killed.

As described previously^{1,2}, the systemically injected L-dopa is trapped in the capillary walls of the normal brain tissue, and shows in the fluorescence microscope an intense greenish fluorescence in the endothelial cells and the pericytes. *In vivo* and *in vitro* experiments^{2,3} have shown that the cellular fluorescence primarily represents dopamine, formed locally from the

exogenous L-dopa by decarboxylation. Inhibition of monoamine oxidase results in a strong accumulation of dopamine, which is reflected in the intense fluorescence in the capillary wall cells. This phenomenon—which is unique for capillaries in the CNS—represents a barrier mechanism for L-dopa, and it rests on two special properties of the wall cells of the cerebral capillaries: first, the presence in the cells of a decarboxylating enzyme that efficiently converts L-dopa to dopamine; and secondly, the relative impermeability of the endothelial cells to catecholamines^{2,3}.

The irises implanted in the cerebral tissue are rapidly revascularised, both from the brain parenchyma and the pial vessels. As shown in an earlier study⁶, using perfusion of the vascular system with a fluorescent plastic particle suspension, a circulation in the transplant starts as soon as 1 d after transplantation. At day 5 a sparse network of vessels supplies almost the entire transplanted tissue, and at 3 weeks the vascular density is close to that of the normal iris.

The capillaries in the implanted iris were tested for their barrier properties towards L-dopa at times varying between 3 and 60 d after transplantation. No fluorescent capillaries were detected within the iris tissue in any of the experimental groups. Figure 1a illustrates normally fluorescent capillaries in the lower portion of the picture. At the zone of transition between the parenchyma and the transplant (that is, within the scar tissue surrounding the transplant) an abundance of intensely fluorescent tortuous capillaries occur, whereas none may be seen inside the transplant. When, in the microscope, switching between ultraviolet light and phase-contrast optics we could observe directly how the fluorescent capillaries in the border zone lost their fluorescence abruptly as they penetrated into the iris tissue.

The lack of a normal blood-brain barrier for amines in the implanted irises was further substantiated through intravenous injections of 6-OHDA. This neurotoxic catecholamine analogue

does not normally pass through the blood-brain barrier. The ability of systemically administered 6-OHDA to cause damage to catecholamine axons in the CNS has therefore been used as an index for the efficiency of the blood-brain barrier¹⁰. In animals bearing iris transplants in the CNS, the 6-OHDA treatment resulted in a total destruction of the regenerated noradrenergic terminal network in the iris. The axons had degenerated up to the site of ingrowth from the brain tissue (Fig. 1d), that is, up to the border zone between the transplant and the surrounding brain parenchyma. The fluorescence microscopical picture of the lesioned axons resembled that observed in the regenerated central noradrenergic terminal network in 2-4-month-old iris transplants of animals not treated with 6-OHDA (Fig. 1e). For comparison a corresponding part of the dilator from a 1-month-old transplant is shown in Fig. 1f. At this stage the regenerated central adrenergic terminal network shows no sign of spontaneous axonal degeneration.

In the reverse experiment—transplanting embryonic CNS tissue to the anterior chamber of the eye—the central tissue is revascularised from the peripheral vessels in the host iris^{8,11}. By as early as 5 d after transplantation—a time when the revascularisation of ocular implants has been found to be almost complete⁸—the wall cells of the capillaries within the CNS transplant showed a moderate fluorescence after L-dopa treatment. A strong capillary fluorescence was found 10 d and 30 d after transplantation (Fig. 1b and c). Fluorescence was never seen in the capillaries of the host iris or in the vessels bridging between the host iris and the CNS transplant. That the fluorescent capillaries in the CNS tissue were functioning was shown in the specimens in which the vascular system had been perfused with Indian ink. In these specimens Indian ink was found in the lumen of the fluorescent capillaries.

Our results thus show that in the new circulation established from the cerebral vessels in the transplanted peripheral tissue, the capillaries will not acquire the normal barrier properties towards amines and amine precursors, characteristic for cerebral capillaries. In the animals perfused with trypan blue there was an extravasation of the dye confined to the iris transplant, suggesting that there may be a more general defect in the capillaries of cerebral implant. In the reverse situation, with ocular implants of CNS tissue, the new circulation established from peripheral vessels in the cerebral tissue exhibited a fluorescent microscopically visible blood-brain barrier towards exogenous L-dopa, and these properties developed as soon as the new circulation was established. These observations show that the barrier properties of the new circulation are determined not by its origin, but by the revascularised tissue.

One possible explanation for this is that the new vascular supply occurs solely in the original capillary network of the transplants. For several reasons this seems unlikely. Thus, it has been found in skin grafts^{12,13} that a recirculation in parts of the original vascular bed will occur during the first few days after transplantation. From the day 4 to 12, however, these vessels degenerate and, concomitantly, there is an ingrowth of new vessels into the graft from the transplantation bed¹². From our own study of the revascularisation process of irises implanted in the caudal diencephalon⁸ it also seems that a recirculation of original vessels might occur in some restricted areas of the transplant during the first few days. From the second postoperative week onwards, when the new vascularisation extends within the iris, the vascular supply changes, however, into such irregular and abnormal patterns that may only be explained in terms of the formation of a new capillary network.

There is thus very good support for the assumption that the capillary networks at least in the cerebral implants are newly-formed, and consequently, that the barrier characteristics of the newly-formed capillaries are determined by the properties of the tissue in which the new circulation occurs. There seems to be two principally different mechanisms whereby this could be established, either through the recruitment of old or dormant endothelial cells from the transplanted tissue for the building

of the new capillaries, or—if the capillaries grow in from the transplantation bed—the barrier properties would be actively induced from elements in the cerebral tissue. It is interesting that after a mechanical or electrolytic lesion in the brain there is a pronounced regeneration of the cerebral capillaries into the lesion, and—in contrast to those forming in the peripheral transplants—these newly-formed vessels acquire the barrier properties for L-dopa soon after they are formed¹⁴. It seems conceivable that the same regeneration mechanism could operate in the revascularisation of both transplant and scar tissue and that the development of a blood-brain barrier in the wall cells is dependent on the tissue into which the capillaries grow.

From the present observations it is evident that the cerebral iris transplant, reinnervated by regenerated central noradrenergic fibres, provides an interesting situation in which central axons extend out from the barrier-protected central tissue into the unprotected environment of the transplant. Our previous studies on this reinnervation process⁴⁻⁶ have shown that the central fibres survive well during the first few weeks (Fig. 1f), and they establish within a month after transplantation functional contacts with the smooth muscle in the transplant⁵. During the second and third postoperative months, however, the central fibres in the transplant often show signs of direct structural damage, and at 2-4 months after transplantation the central terminal network has in many cases degenerated (Fig. 1e).

The blood-brain barriers are generally regarded as mechanisms whereby harmful substances in the circulation are excluded from entering the CNS. In situations where the barrier function is damaged or deficient—such as in the cerebral iris transplant—the CNS elements should therefore be more vulnerable. In a region of the CNS normally lacking blood-brain barriers, namely the pituitary gland, the central innervation shows in fact abundant ultrastructural and fluorescence histochemical signs of acute damage, and it has been suggested that the axons innervating this unprotected region undergo continuous degeneration-restitution cycles^{15,16}.

The integrity of the blood-brain barriers therefore seem to be necessary for the protection of cerebral tissue from direct structural damage. It has been proposed^{17,18} that abortive regeneration in the CNS may be attributable to an inhibition of axonal regrowth by immunological mechanisms that become mobilised and obtain access to the lesioned axons because of the breakdown of the blood-brain barriers at the site of injury. According to this theory the unprotected brain sites will expose brain autoantigens, normally sequestered by the blood-brain barriers, and sensitised cells or autoantibodies will attack the site of lesion at which they have free access to the antigens¹⁸. Disturbed vascular permeability in the CNS has also been implied in other pathological conditions, for example, in multiple sclerosis^{19,20}. If, indeed, a deficient blood-brain barrier is the cause of long term degeneration of central axons, this could be a primary aetiological factor in neurological disorders.

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Contractility of smooth muscle cells of rabbit aorta in tissue culture

THE involvement of smooth muscle cells (SMC) from the media of elastic arteries has been implied in the aetiology of atherosclerosis². Aortic tissue cultures have been studied repeatedly to examine the ability of SMC to synthesise macromolecular proteins, and collagen and elastic fibres. Ross³ has shown that aortic cultured cells retained all the morphological characteristics of SMC up to week 8 of culture. By week 4 micro-fibrils identified as elastic fibres appeared close to the cells. On the other hand, Ouzilou *et al.*⁴ showed that the cultured aortic fragments can be used as a suitable model to study the metabolic properties of aortic smooth muscle. The explants retained, for at least a week, the ability to synthesise the proteins of the medial matrix at a rate that decreased with the age of the rabbits from which the aortic specimens were obtained.

To correlate the synthetic activity with the physiological state of the SMC in tissue culture, we have examined the response to drugs and electrical stimulation of both the explants and cells at different stages of evolution. The contractile response of the explants and cultured cells from young rabbits was tested in a Zeiss inverted microscope with phase contrast optics enclosed in a temperature-regulated chamber at 37 °C. The movements were monitored and registered in a videotape recorder or filmed with an Arriflex camera at a speed of 2.5 frames per s. The films were later projected at 24 frames per s. Drugs were added to the Petri dishes filled with 5 ml Hanks' solution to obtain final concentrations of 10⁻⁶M angiotensin II (At_{II}), 10⁻⁶M noradrenaline (NA), 10⁻⁶M 5-hydroxytryptamine (5 HT) and 50 mM KCl. On the other hand the explants and cells were stimulated electrically by glass electrodes filled with 3 M NaCl with a 1 MΩ tip resistance. Square-wave pulses had a maximum intensity of 10⁻⁵ A and 1 s duration.

No contractile response of subcultured cells, confluent for 3 weeks or non-confluent, was detected under the action of

drugs and electrical stimulation in 30 experiments. This confirms a previous report by Martin and Sprague⁵. In one experiment only, confluent cells in a 21-d primary culture (Fig. 1) contracted with NA and KCl without response to At_{II}. An undulatory movement affected most cells in the fields. Groups of cells organised in parallel bundles contracted at the same time, asynchronously with respect to other contiguous bundles. This contraction shortened single cells very slightly and was very slow. To observe this, the film had to be projected at fast speed. The duration of each contraction was between 10 and 20 s. In contrast with the cultured cells, for up to 3 weeks the explants always responded with a contraction synchronous with the electrical stimulation.

To quantify the spasmogenic response of the aortic fragments, helical strips maintained in culture for different periods

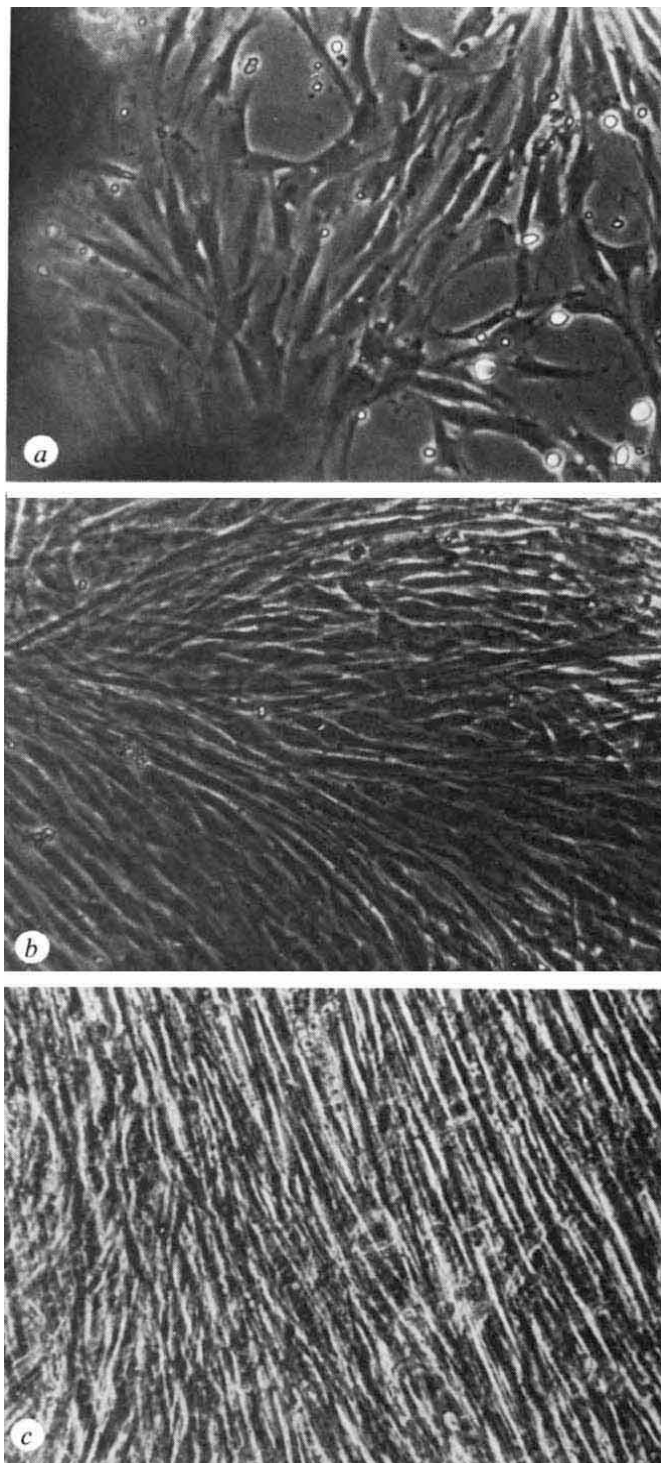


Fig. 1 *a*, Phase-contrast photography of spindle-shaped cells growing out of young rabbit aortic explants (dark area) after culture for 11 d ($\times 145$). These cells did not contract with electrical stimulation, 5-HT, NA, KCl or At_{II}. *b*, Phase-contrast photography of aortic cells at very high density. These cells have been subcultured once and kept confluent for 4 weeks. Criss-crossed multilayers can be observed. There was no contractile response with either drugs or electrical stimuli ($\times 125$). *c*, Photography from an area of a long term (22 d) primary culture which contracted with 10⁻⁶M NA and 50 mM KCl. There was no response to 10⁻⁶M At_{II}. Young rabbits of either sex (about 800 g) were killed by a blow on the head. The thoracic aorta was excised, washed in Hanks' solution, and the adipose tissue and adventitia removed, at room temperature. Fragments of about 1 mm² were put in Petri dishes in MEM Eagle's solution in Earle's buffer, to which 10% calf serum (GIBCO) had been added. Five or six fragments were installed in each dish under glass slides and equilibrated with a 95% O₂ and 5% CO₂ mixture. The media were renewed twice a week. In some cases helical strips have been prepared by cutting the aortae at an angle of 20° (ref. 5). Strips were then kept in Petri dishes and cultured in the same media as the smaller fragments, but kept free (without slides) in a gyratory shaker at 10 r.p.m.

were installed successively in 10 ml organ baths, regulated at 35 °C and perfused with modified Ringer solution⁷. The isotonic contractions of the strips attached to writing levers that provided a fourfold magnification at a constant tension of 2 g, were recorded on smoked drums. Cumulative dose-response curves to NA and At_{II} were obtained by exposing the strips to increasing concentrations of the drugs in the chamber once the contraction provoked by the previous dose had been stabilised. The strips were washed between doses, when the spasmogenic action of KCl was tested. Typical experiments are presented in Fig. 2. Very rapidly, after 1 d in culture conditions, the reactivity to NA started to decrease, and disappeared completely at day 3, when the response to At_{II} started to decline, and was practically suppressed at day 8, when the strips still contracted when depolarised by KCl.

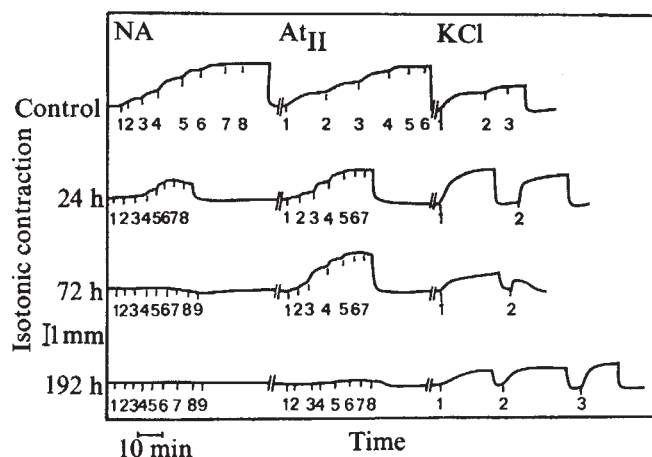


Fig. 2 Evolution of the contractile response of aortic strips after 24, 72 and 192 h culture. Cumulative dose-response curves to NA and At_{II} , and non-cumulative curves in the presence of a solution in which NaCl is partially replaced by KCl. Drug concentrations were: NA(M): 1, 1×10^{-8} ; 2, 2×10^{-8} ; 3, 5×10^{-8} ; 4, 2×10^{-7} ; 5, 5×10^{-7} ; 6, 2×10^{-6} ; 7, 5×10^{-6} ; 8, 2×10^{-5} ; 9, 5×10^{-5} ; At_{II} (M): 1, 2×10^{-9} ; 2, 5×10^{-9} ; 3, 2×10^{-8} ; 4, 5×10^{-8} ; 5, 2×10^{-7} ; 6, 5×10^{-7} ; 7, 1×10^{-6} ; 8, 2×10^{-6} ; KCl (mM K^+): solutions containing 1, 34; 2, 67; 3, 101.

It is interesting to compare these results with previous studies concerned mainly with the morphology of aortic cultured SMC. Cells in primary cultures, which grow out from the explants and are characterised by a lower myofilament content and an increase in organelles (defined by Fritz *et al.*⁸ as modified SMC), never contract under the action of drugs and electrical stimulation. Subcultured confluent cells, which are currently used as an experimental model for atherosclerosis, are nearly always non-responsive. This lack of spasmogenic response does not seem to be related to an artefact of culture, as in the same experimental conditions isolated cells of guinea pig taenia coli and vas deferens contract spontaneously and when stimulated with carbamylcholine or NA (J.P.M. and M.W., unpublished). Cells of primary cultures may recover the functional capacities of normal aortic SMC as shown by the fact that we were able once to observe a contractile response to NA and depolarisation.

Explants keep their contractility for long periods. Coincidentally the normal histological structure of the organ is conserved during week 1. During week 3, the muscular layer is disrupted but some SMC are still arranged in organised bundles in some loci, mostly in the periphery of the explant, as shown by Fritz *et al.*⁸. As there is no response to At_{II} or NA at this time, however, it must be admitted that either the drug receptors disappeared or there is a fault in the excitation or the excitation-contraction coupling mechanisms. This problem was further explored with the dose-response curves of aortic strips. In fact there is a difference in the timing of the decrease in the response to drugs, the spasmogenic effects of NA being suppressed before those of At_{II} . This suggests *per se* that their

receptors are modified or their number decreases, besides any other change in cell excitability or excitation-contraction coupling. From our results and other histological studies, we can conclude that aortic SMC dedifferentiate when they grow out of the explant. Their cell membrane properties are modified during this process. This phenomenon is slower in the explant probably because of matrix-cell interaction. Subcultured confluent cells are not similar to normal *in vivo* SMC as far as their contractile properties are concerned.

To confirm whether proliferative SMC *in vitro* can be used as a model for the study of atherosclerosis, it will be necessary to determine the physiological status of the cells that proliferate in atheromatose plaques to find out whether SMC lose their contractility in these conditions.

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Allosteric inhibition of the sodium pump by external sodium

WHEN the sodium pump works forward performing Na-K exchange, it is activated by intracellular Na and extracellular K (refs 1-3), but is also inhibited by internal K and external Na (Na_o) (refs 4-8). So far, the inhibition by internal K seems adequately described in human erythrocytes, as fully competitive at three internal sodium sites^{7,8}, but the situation regarding the Na inhibition at the external K sites seems more complicated. The experiments reported here suggest an allosteric interaction of external Na with those sites.

In the presence of Na_o , the curves showing the activation of the pump by external K are sigmoid, while in Na-free medium the curve is apparently hyperbolic; the K_0 for K is lower in Na-free medium, whereas the maximal activation is the same as that in high- Na medium^{3,6,9,10}. The kinetics of activation of the pump in red cells by external K in the presence of high Na_o , has been interpreted assuming that two K ions must bind externally for Na-K exchange to occur¹¹, probably with similar affinities. Even in nominally Na-free medium, the activation of ouabain-sensitive K influx by K_o has been found to be slightly sigmoid at very low K_o concentrations⁶, and for similar conditions, Lew *et al.*¹² have proposed a two-site activation of Na efflux by external K, with a large difference in dissociation constants (4 and 100 μ M).

When the ouabain-sensitive K influx in red cells is measured at fixed K_o concentrations and variable external Na, Dixon plots ($1/v$ against Na_o concentration) show a linear competitive inhibition by Na_o (refs 10 and 13). This would imply that whereas two K ions are needed for the external activation of the pump, one Na ion is enough for inhibition. The linear dependence of $1/v$ on Na_o has been confirmed for cells loaded to have a high internal Na concentration, prepared by the

pCMBS method¹⁴. Similar results for nystatin-loaded cells¹⁵ are presented in Fig. 1a.

The linear inhibition by Na_0 has been interpreted as dead-end at only one of the K sites¹⁴. If it were at the low affinity site, this could only lead to a pseudo-Michaelian behaviour, that is, the activation of ouabain-sensitive K influx by K_0 should be hyperbolic at all Na_0 concentrations; this situation is clearly not met in practice^{3,6,10,11}. Two alternatives remain which are compatible with the observed results: (1) dead-end inhibition at the high-affinity site and (2) binding of Na_0 at neither of the K sites but at a third (allosteric) site (the 'partially-competitive inhibition' case of Dixon and Webb¹⁶). Binding of Na_0 at a third site only, should lead to a reversible change of the state of the K-binding sites, decreasing their affinities differentially to make them seem nearly equivalent at high Na_0 concentrations. This alternative implies that (1) the effect of the 'allosteric transition' is only on the K-affinity and not on the maximal velocity (compatible with the 'direct interaction by vicinity' of

Monod *et al.*¹⁷) and hence the complexes KXX and KXK should lead to the same rate of K translocation inwards and (2) the affinity of the inhibitory site for Na_0 is lower when both K sites are loaded than when no K or only one K is bound¹⁶.

A convenient test between allosteric as against dead-end inhibition is provided by the inspection of Dixon plots¹⁸ of ouabain-sensitive K influx against Na_0 concentration, at very low concentrations of K_0 . In the case of dead-end inhibition, the Dixon plots will still be linear; whereas in the case of allosteric inhibition, they will bend downwards and approach a hyperbola¹⁸ since in this case there is a limiting non-zero K influx in the presence of saturating Na_0 concentrations. One of several experiments, which gave closely similar results, is shown in Fig. 1b. The inhibition of K influx is clearly a non-linear function of Na_0 in these conditions. If the inhibition were hyperbolic, it should conform to the general equation

$$1/v = (1/v_{i=0} - 1/V_{\max}) [(1 + [\text{Na}_0]/K_{\text{Na num}}) / (1 + [\text{Na}_0]/K_{\text{Na denom}})] + 1/V_{\max} \quad (1)$$

(Compare Dixon and Webb¹⁶) formally analogous to those described by Cleland¹⁹. If the value of the ordinate for zero- Na_0 is subtracted from each curve we obtain

$$1/v - 1/v_{i=0} = (1/v_{i=0} - 1/V_{\max}) ([\text{Na}_0]/K_{\text{Na num}} - [\text{Na}_0]/K_{\text{Na denom}}) / (1 + [\text{Na}_0]/K_{\text{Na denom}}) \quad (2)$$

In general, and for any number of K sites

$$1/v - 1/v_{i=0} = A / (1 + K_{\text{Na denom}}/[\text{Na}_0]) \quad (3)$$

where A is independent of Na_0 and represents the maximal value of the function. The conformity with equation 3 of each set of data in Fig. 1b was tested by plotting the reciprocal of $(1/v - 1/v_{i=0})$ against the reciprocal Na_0 concentration¹⁹. Good straight lines were obtained by least squares regression (linear regression coefficients > 0.96), from which the following parameters were derived (mean $\pm$ s.d.): (1) 0.027 mM K_0 ; $A = 157 \pm 39 \text{ mmol}^{-1} \times 1 \text{ cells} \times \text{h}$, $K_{\text{Na denom}} = 37.1 \pm 10.2 \text{ mM}$ and (2) 0.053 mM K_0 ; $A = 56.5 \pm 11.5 \text{ mmol}^{-1} \times 1 \text{ cells} \times \text{h}$, $K_{\text{Na denom}} = 45.4 \pm 9.9 \text{ mM}$. The curves drawn in Fig. 1b represent the hyperbolae calculated from the above parameters. The values of A imply that at 0.027 mM K_0 , the minimal K influx attainable at infinite Na_0 is 0.00613 mmol per 1 cells per h (96.9% inhibition of control influx), while at 0.053 mM K_0 it is 0.0172 mmol per 1 cells per h (96.7% inhibition). Both $K_{\text{Na denom}}$ values are, however, not statistically different. This is in agreement with equations 2 and 3 which show that while A is a function of $1/v_{i=0}$, $K_{\text{Na denom}}$ is an independent parameter; it represents the dissociation constant for Na binding at the third site, once the two K sites have been occupied¹⁶.

To minimise changes in the external specific activity of ^{42}K resulting from leaking from the cells, all the experiments like

that of Fig. 1b were conducted at the lowest feasible haematocrits (0.05–0.1%). The variation of the supernatant K concentration (mean of initial and final) between the zero- Na_0 and the highest- Na_0 tubes was usually of about +5%; an independent control experiment (not presented) showed that the

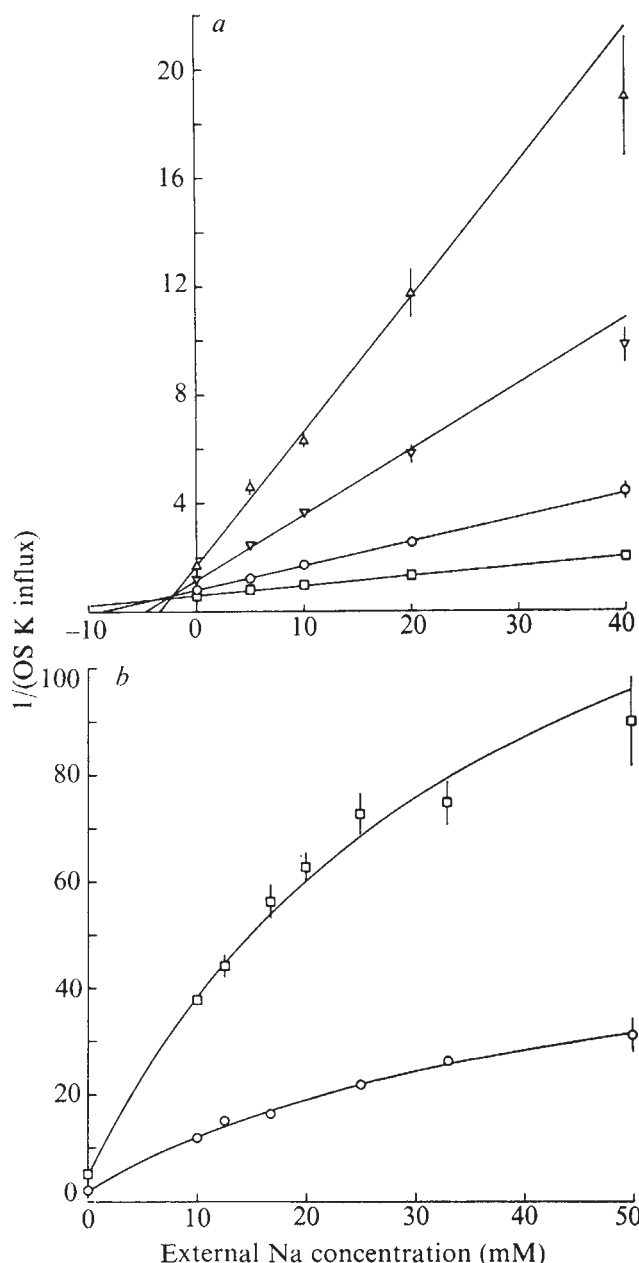


Fig. 1 (a) Linear inhibition of the ouabain-sensitive (OS) K influx by external Na. Red cells loaded by the nystatin method against: 80.5 mM Na, 52 mM K and 20 mM choline were used. Washed cation-loaded cells were resuspended in a cold medium containing: 130 mM choline, 2 mM Mg, 15 mM Tris (pH 7.9 at 20 °C) 153.5 mM chloride, 10 mM glucose. ^{42}K influx was then measured in triplicate at the external K and Na concentrations shown (by choline replacement) $\pm 10^{-4}$ M ouabain. The incubation was for 40 min at 37 °C, in a volume of 5.25 ml and at a final haematocrit of 0.34%. The bars indicate $\pm$ s.e.m. on the reciprocal velocities, calculated according to Wilkinson²⁴. The lines have been drawn by eye. Δ , 0.077 mM K_0 ; ∇ , 0.12 mM K_0 ; $\circ$, 0.21 mM K_0 ; $\square$, 0.35 mM K_0 . (b) Hyperbolic inhibition of the ouabain-sensitive K influx by external Na, at low external K. Erythrocytes loaded as in a. ^{42}K influx was measured in quadruplicate at 0.027 ($\square$) and 0.053 ($\circ$) mM K_0 (average concentrations as assayed in the supernatants), at varying Na_0 concentrations (choline chloride replacement) $\pm 10^{-4}$ M ouabain. The incubation was for 60 min at 37 °C, in a volume of 16.8 ml and at a final haematocrit of 0.08%. The reciprocal ouabain-sensitive K influx has been plotted against Na_0 concentration. The bars indicate $\pm$ s.e.m.; the lines represent the hyperbolae fitted as described in the text.

associated change in external specific activity at the highest- Na_0 with respect to the zero- Na_0 tubes could account for not more than -2% deviation of the highest point from a straight line drawn through the points at zero and 10 mM Na_0 . On the other hand, the possibility that the observed behaviour of the K influx was caused by the existence of a small and constant component of the K influx due to K-K exchange, can be ruled out since the ouabain-sensitive K-K exchange in red cells is completely abolished at the internal Na and K concentrations used²⁰.

Having proposed a third external pump site which does not bind K, the question remains as to whether Na-binding to this site leads to Na translocation inwards. Since $K_{\text{Na denom}}$ is about 40 mM, in conditions of saturating external K concentration (say 15 mM K_0 at 130 mM Na_0), one would predict a relatively large ouabain-sensitive Na influx (25% of that at 0 K_0 , 130 mM Na_0). This is clearly not the case, since Garrahan and Glynn²¹ have shown that there is a negligible ouabain-sensitive Na influx in the present conditions.

But, the supposition that the allosteric site plus the two K sites constitute the three external Na sites for Na-Na exchange in the absence of external K, seems attractive²². The disagreement between this idea and the negligible ouabain-sensitive Na influx at saturating K_0 could be reconciled if only NaXNa (and possibly NaKXNa) can lead to ouabain-sensitive Na influx, but not NaKXK . In this connection, it will be recalled that when the ouabain-sensitive Na efflux from red cells is measured in a K-free medium and the Na_0 concentration is increased from 0 to 150 mM, the uncoupled Na efflux reaches a minimum at about 5 mM Na_0 (refs 12 and 23) before Na-Na exchange is turned on. Since the affinity of the third site for Na_0 should increase maximally in the absence of external K, the third external site is a likely candidate to be the one involved in the inhibition of the uncoupled Na efflux by low Na_0 concentrations.

Recent studies of ATP hydrolysis in resealed ghosts as a function of Na_0 lend support to this idea (I. M. Glynn, personal communication). If this were the case, binding of Na to the third site only (in the absence of K_0), would not lead to ouabain-sensitive Na influx, but would act instead as a 'brake' for the pump. The increase of Na_0 concentration beyond 5 mM (always in K-free medium) would then lead to occupation of the two K sites by Na and hence to Na-Na exchange. This implies that the affinity for Na_0 would be different at the different sites, although Garay and Garrahan⁷ concluded that three identical low affinity sites existed for Na-Na exchange.

It is then possible, that the allosteric Na site responsible for the partially competitive inhibition of K influx, the high-affinity Na site responsible for the inhibition of the uncoupled Na efflux and the 'missing' site necessary for a three-site activation of the ouabain-sensitive Na influx, are just different states of the same binding group: a third external (Na) site of the Na pump.

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Molecular basis for formation of lipid sound lens in echolocating cetaceans

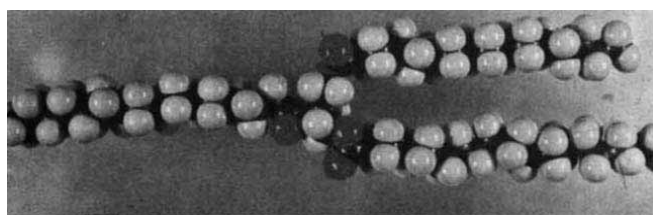
Most echolocating porpoises and small whales (odontocete) possess a fatty protrusion on the forehead and a peculiarly formed lower jaw which flares into a posterior flange. Overlying this flange is a region of highly fatty tissue referred to by Norris¹ as an acoustic window. The fatty tissues (>80% lipid) of the mandible and the melon are believed to be associated with sound transmission¹⁻³. It is proposed^{4,5} that the melon functions as a sound lens, a concept consistent with the view that it is heterogeneous in terms of sound velocity and refraction⁶. Recent studies⁷⁻¹³ revealed that the lipids of acoustic tissues are different from those of the surrounding tissues. For example, the acoustic tissues contain triacylglycerols and wax esters rich in short and medium chain (C_8 - C_{12}) acids, whereas blubber tissues are composed primarily of triacylglycerols containing long chain (C_{14} - C_{22}) acids. In the families Delphinidae⁷⁻⁹ and Monodontidae¹², isovaleric acid (3-methyl butyric acid) and longer iso (*gem*-dimethyl) acids are present in large amounts in acoustic tissues. Furthermore, certain areas, such as the acoustic window and the inner melon, contain almost exclusively 1,3-diisovaleroyl-2-acylglycerols and isovaleroyl wax esters (Fig. 1). These compounds are replaced by medium and long chain triacylglycerols in adjacent areas. Thus, specific lipid compositions with various proportions of branched structures are found in the putative areas of sound transmission^{14,15}. The intriguing association between proposed acoustic pathways and unique lipid composition led us to study the acoustic properties of these lipids.

Our studies with acoustic tissues of the porpoise family Delphinidae relate lipid composition to ultrasonic velocity, density and compressibility. The results show that relatively small changes in the ratio of wax esters to triacylglycerols, both rich in branched structures, induce substantial alterations in the sound properties of the lipid medium. Moreover, we show here with a model system of trioctadecenoylglycerol (triolein) and hexadecyloctadecenoate (cetyl oleate) that these changes could not be achieved through the use of lipids commonly present in most animal tissues.

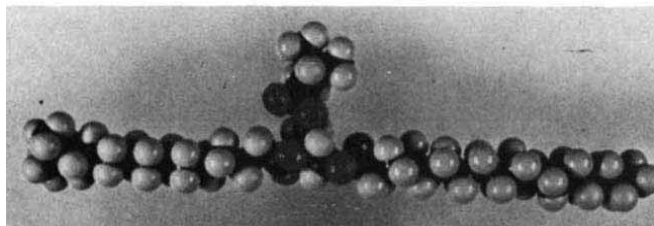
The velocity of ultrasound, c , is related to the compressibility and density by the following equation:

$$c^2 = \frac{1}{\beta d} \quad (1)$$

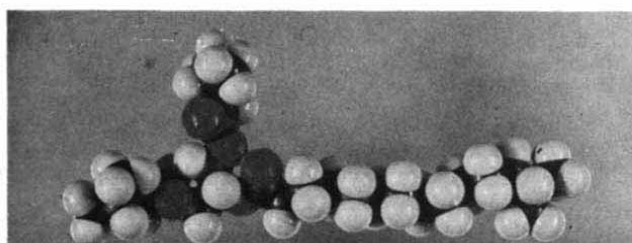
where d is the density of the medium and β is the compressibility. We measured the densities and ultrasonic velocities, and calculated the compressibilities of acoustic lipids pooled from several porpoises (*Stenella graffmani*). (The calculation yields the dynamic compressibility at the frequency of the ultrasound used in the velocity measurement (4 MHz). This value approximates the adiabatic compressibility. We can expect the values of velocity and compressibility to be valid at lower frequencies as well.) Pure triacylglycerols (65 g) and wax esters (15 g), which together comprise more than 99% of the acoustic lipids, were isolated by preparative thin-layer chromatography⁷⁻¹⁰. The



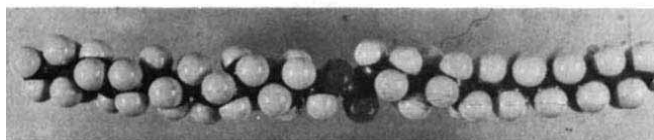
a Long-chain triacylglycerol



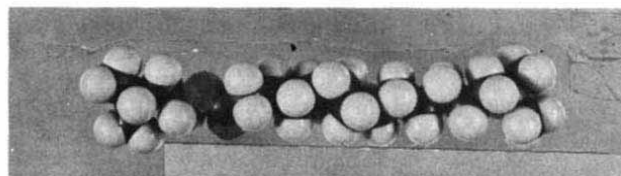
b Monoisovaleroyldiacylglycerol



c 1,3-Diisovaleryl-2-acylglycerol



d Long-chain wax ester



e Isovaleroyl wax ester

Fig. 1 Molecular models depicting several classes of triacylglycerols and wax esters present in porpoise acoustic tissues and other animal tissues. *a*, Long chain triacylglycerols containing long chain (C_{10} – C_{18}) acids on each carbon atom of the glycerol moiety are commonly found in animal tissues. In porpoise acoustic tissues, these triacylglycerols contain about 32 mol % of isoacids¹³. Specific example given here: 1,2-dipalmitoyl-3-stearoylglycerol. *b*, Monoisovaleroyldiacylglycerols, containing 2 mol of long chain acids for each mol of isovaleric acid, are present in small amounts in the porpoise acoustic tissues. Specific example given here: 1-isovaleroyl-2-isopentadecanoyl-3-palmitoylglycerol. *c*, 1,3-diisovaleryl-2-acylglycerols, containing 2 mol of isovaleric acid for each mol of long chain acids, constitute a major fraction of the lipids of the acoustic tissues. These glycerides contain about 20 mol % of long chain isoacids¹¹. Specific example given here: 1,2-diisovaleryl-3-isopentadecanoylglycerol. *d*, Long chain wax esters, containing long chain (C_{10} – C_{18}) alcohols esterified with long chain acids, are commonly present in animal tissues. In the porpoise acoustic tissues, these wax esters contain about 40 mol % of isoacids¹⁰. Specific example given here: hexadecylhexadecanoate. *e*, Isovaleroyl wax esters, containing long chain alcohols esterified with isovaleric acid, constitute a significant fraction of the lipids from porpoise acoustic tissues. Specific example given here: isopentadecylisovalerate.

triacylglycerols contained 68% of 1,3-diisovaleryl-2-acylglycerols, 11% of monoisovaleroyldiacylglycerols and 21% of long chain triacylglycerols (Fig. 1). (All percentages reported here are on a weight basis.) The wax esters contained 51% of isovaleroyl wax esters and 49% of long chain wax esters. Our measurements (Figs 2a, 3a and 4a) were limited to the mixtures of triacylglycerols and wax esters containing up to 30% wax esters, the maximum fraction present in most marine porpoises^{14,15}. For comparison, measurements (Figs 2b, 3b and 4b) were made on mixtures of triolein and cetyl oleate (Nucheck Prep. Inc.). The ultrasonic velocity was measured with a conventional sing-around velocimeter at 4MHz. Because of the difficulty of purification of large quantities, only densities were measured for pure 1,3-diisovaleryl-2-acylglycerols and wax esters (Fig. 2c).

The densities of all three sets of mixtures were less than the values calculated for ideal mixtures of liquids without intermolecular interactions (Fig. 2a, b, and c). The ultrasonic velocities of triolein–cetyl oleate mixtures were also lower than those calculated for ideal mixtures (Fig. 3b), although the deviation from the calculated values was not very large. In contrast, the lowering of the ultrasonic velocity was very pronounced for the triacylglycerol–wax ester system from the porpoise acoustic tissues (Fig. 3a). Curves of compressibility against composition are similar for porpoise triacylglycerol–wax ester and triolein–cetyl oleate (Fig. 4a and b). In the latter system (Figs 2b, 3b and 4b), however, the increase in compressibility is related

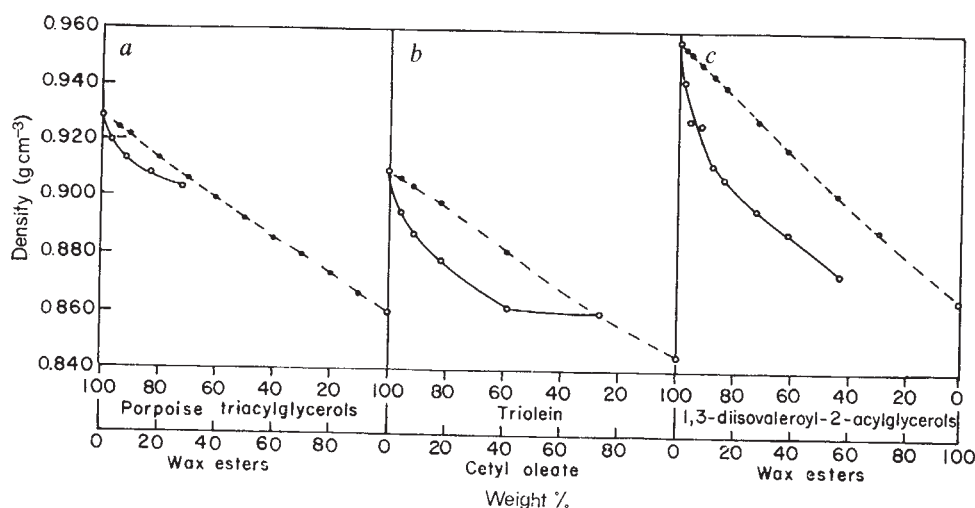


Fig. 2 Density against lipid composition. The measurements were made using a 2-ml pycnometer and an analytical balance. The samples were isolated in an atmosphere of nitrogen. Each fraction was dried carefully and traces of solvent were removed under high vacuum for 24 h at 40–50 °C. The measurements, made at 23 °C, had a precision of $\pm 0.003 \text{ g cm}^{-3}$. *a*, Porpoise triacylglycerols–wax esters system. Triacylglycerols and wax esters were obtained from acoustic tissues of several porpoises. *b*, Triolein (tri-octadecenoylglycerol)–cetyl oleate (hexadecyloctadecenoate) system. *c*, 1,3-Diisovaleryl-2-acylglycerols–wax esters system. Both fractions were obtained from the melon tissues of a single porpoise (*S. graffmani*). The wax esters, which contained 56 mol % isovaleric acid, exhibit a slightly higher density value than that of the wax esters in *a*. ●, Ideal mixture; ○, experimental.

mainly to a decrease in density rather than in ultrasonic velocity, whereas in the former system, the increase in compressibility is related to a large decrease in ultrasonic velocity and a smaller decrease in density (see equation (1)). Thus the porpoise lipids have an ultrasonic velocity profile very different from that of the triolein-cetyl oleate system.

The ultrasonic velocity of porpoise triacylglycerols is much lower ($1,383 \text{ m s}^{-1}$) than that of triolein ($1,460 \text{ m s}^{-1}$) and decreases more rapidly as wax esters are added (Fig. 3a) than does the ultrasonic velocity of triolein on addition of cetyl oleate (Fig. 3b). Thus, by virtue of specific molecular structures and intermolecular associations of their components, porpoise acoustic lipids give rise to lower ultrasonic velocities which enable the required acoustic refraction to take place. Furthermore, the steep decline in ultrasonic velocity as a function of composition (Fig. 3a) allows the cetacean to control sound refraction by means of small changes in composition.

Norris and Harvey¹⁸ have shown that in the melon of the porpoise, *Tursiops truncatus*, a central core of lipids of low ultrasonic velocity ($1,273\text{--}1,376 \text{ m s}^{-1}$) is surrounded by a graded high velocity shell (to $1,682 \text{ m s}^{-1}$). Figure 3a shows that the porpoise triacylglycerol-wax ester system yields velocities of $1,360\text{--}1,383 \text{ m s}^{-1}$ for compositions of 0–30% wax esters. It seems likely that the lower portion of the ultrasonic velocity range ($1,273\text{--}1,360 \text{ m s}^{-1}$) obtained by Norris and Harvey results from deposition of a virtually pure system of 1,3-diisovaleroyl-2-acylglycerols and wax esters because the acoustic window and the inner melon are composed almost exclusively of these compounds^{14,15} and as our measurements of this system (Fig. 2c) show that the density declines steeply over a wide range of composition, a more pronounced decline than in either of the other systems.

The biochemical events that led to the deposition of the isovaleroyl lipids in areas of sound transmission can be explained as follows. At the site of deposition L-leucine provides the isovaleryl CoA that introduces isovaleric acid into the lipid structure¹⁷. Isovaleryl CoA also seems to undergo chain elongation to provide the longer chain isoacids¹⁷. In most mammalian systems isovaleryl CoA is degraded rapidly to acetate and acetoacetate¹⁸. Therefore, the modifications in biosynthesis that led to the formation

Fig. 3 Ultrasonic velocity against lipid composition. The measurements were made at 23°C , by a precalibrated ring-around velocimeter of 10 cm path length with a precision of $\pm 1 \text{ m s}^{-1}$. The temperature was measured with a calibrated mercury thermometer and is accurate to $\pm 0.5^\circ\text{C}$. a, Porpoise triacylglycerols-wax esters system. The ultrasonic velocity value for pure wax esters was calculated using Schaaffs' equation²² which relates molecular composition and density to ultrasonic velocity. b, Triolein-cetyl oleate system. ●, Ideal mixture; ○, experimental.

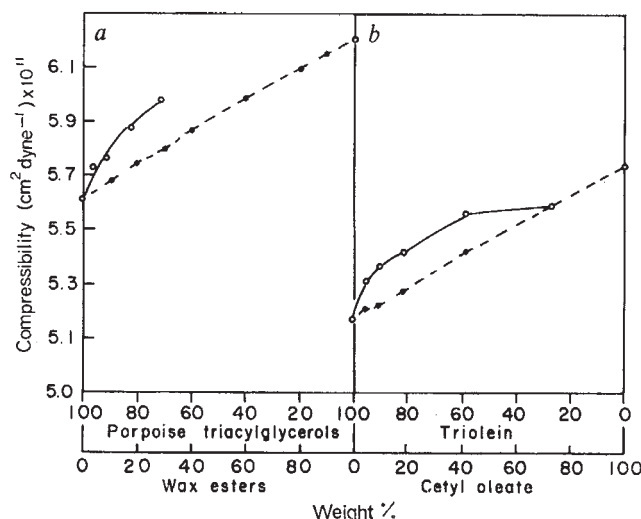
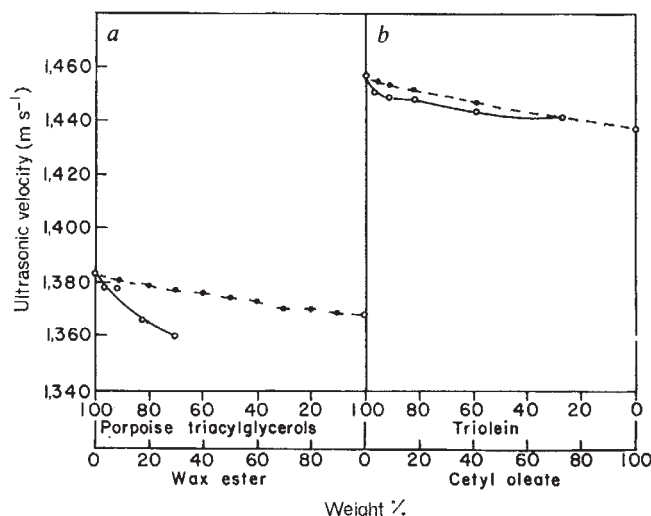


Fig. 4 Compressibility against lipid composition. Compressibilities were calculated from the measured values of density and ultrasonic velocity by use of equation (1). a, Porpoise triacylglycerols-wax esters system. b, Triolein-cetyl oleate system. ●, Ideal mixture; ○, experimental.

of the lipids of acoustic tissues must have involved the activation of enzymes mediating the direct incorporation of isovaleryl CoA into lipid. Another advantage of depositing isovaleroyl lipids, which have the desired physical properties (low ultrasonic velocity, fluidity and stability to oxidation), is that their biosynthesis is largely independent of fluctuations in fatty acid distribution of dietary lipids¹⁹.

In summary, from our findings we can explain, on a molecular basis, why anomalous metabolic processes have evolved in echolocating cetaceans to form massive deposits of specialised lipids in certain areas of the head. It seems that one objective for the biosynthesis and deposition of acoustic lipids was the formation of a three-dimensional matrix of ultrasonic velocities that constitute a sound lens. The results show that the cetacean can react to changes in the environment by making a small change in the lipid composition, thereby achieving a major acoustic accommodation. We have suggested here how modifications in the metabolism of Delphinidae resulted in such an unusual and specialised role for lipid. On the basis of these results, we propose that the acoustic lipids containing short chain and medium chain acids found in other cetaceans^{20,21} also serve in sound focusing.

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Suppression of murine virus leukaemogenesis by thioglycollate, a bacteriological culture medium that affects macrophage peroxidase

INFECTION of mice with an oncornavirus such as Friend leukaemia virus (FLV) results in splenomegaly, hepatomegaly, blood cell dyscrasia and eventually death¹⁻³. Such leukaemias can often be prevented or suppressed by either specific immunisation with a vaccine prepared from the virus or leukaemic cells⁴⁻⁵, by treatment with non-specific enhancers of immune responsiveness such as bacterial lipopolysaccharides or polynucleotides⁶⁻⁸, or by an interferon inducer like statolon^{9,10}. Activated macrophages are thought to be the cells of the reticuloendothelial system primarily involved in nonspecific anti-tumour immunity. Since enhanced metabolic activity of phagocytes has been associated with wide spectrum microbicidal ability, it was interesting to determine whether thioglycollate treatment of mice would stimulate their macrophages and thereby affect FLV-induced leukaemogenesis. *In vitro* studies revealed that phagocytosis causes stimulation of peroxidase activity and H₂O₂ production by phagocytic cells from different sources¹². It is well established that the combination of peroxidase, H₂O₂ and a halide such as chloride or iodide exerts a potent antimicrobial effect at acidic pH¹³⁻¹⁸. We now report marked inhibition of FLV-induced leukaemogenesis in mice injected with thioglycollate; this inhibition could possibly be related to increased peroxidase and glucose-6-phosphate dehydrogenase (G6PD) activities of peritoneal exudate (PE) cell macrophages in the treated animals.

Young adult ICR mice (Jackson Laboratories) were injected intraperitoneally with 0.5 ml of sterile thioglycollate medium (Difco). Two days later PE cells were collected; about 85% of them were typical macrophages. The peritoneal resident (PR) cells from untreated animals consisted of about 35% macrophages. PE and PR cells pooled from six to eight mice per group were tested for G6PD and peroxidase activities. G6PD was determined in intact cells suspended in glycerin by assessing NADPH formation as measured by the increased absorbance at 340 nm¹⁷. Peroxidase activity of cell homogenates was determined by guaiacol colour change at 470 nm¹⁸. The cell densities from both normal and treated mice were adjusted to 6×10^6 viable nucleated cells per cuvette. Table 1 shows that PR cells contain negligible amounts of peroxidase activity. PE cells from thioglycollate-treated animals contain significant quantities of this enzyme activity. PE cells also exhibit six times as much G6PD as PR cells.

Pretreatment with thioglycollate markedly suppressed FLV-induced leukaemogenesis (Fig. 1). An FLV preparation standardised by *in vitro* and *in vivo* assays for oncornavirus activity was used for these experiments¹⁹. Between

500 and 1,000 ID₅₀ of a stock preparation of FLV, consisting of both leukaemogenic and focus-forming viral agents, free of LDH and LCM¹⁹, were injected intraperitoneally into mice injected 2 d previously by the same route with thioglycollate. Spleen weights of these mice were significantly less than those of animals infected with FLV without previous treatment with thioglycollate (Fig. 1). Reduced spleen weights were evident in treated animals as late as 30 d after virus infection when control mice had spleen weights averaging 1,500-2,000 mg.

Mice infected with FLV generally show marked immunosuppression²⁰. We, therefore, wanted to determine if thioglycollate could modify the effect of FLV infection on the immune response of mice to sheep red blood cells (SRBC). Additional groups of mice were injected intraperitoneally with 0.5 ml of thioglycollate 2 d before FLV infection. Eight days later these mice, as well as untreated controls, were challenged by interperitoneal inoculation of 0.5 ml of a 2% suspension of washed SRBC. Four days later the mice were killed and their spleen cells tested for haemolytic antibody plaque-forming cells (PFC) by the standard haemolytic plaque assay in agar gel²¹. Splenic PFC for control mice given neither virus nor thioglycollate were also determined. The results of a representative experiment (Table 2) show that mice injected with thioglycollate before FLV infection developed many more splenic PFCs than those given only FLV. Untreated FLV-infected animals responded to SRBC with fewer than 2,000 PFC per spleen. Control mice with SRBC alone had more than 68,000 PFC per spleen; uninfected mice given thioglycollate before SRBC developed about half this number of PFC. Infected mice pretreated with thioglycollate had more than 20,000 PFC per spleen; this was only moderately fewer than the PFC in the spleens of control animals injected with thioglycollate alone. The difference between the PFC response of FLV-infected mice pretreated with thioglycollate and that of untreated FLV-infected mice was highly significant ($P < 0.001$).

G6PD is the initial enzyme of the hexose monophosphate shunt (HMS) in carbohydrate metabolism²². It is widely accepted that *in vitro* phagocytosis stimulates HMS activity and, therefore, H₂O₂ production²³⁻²⁵. Thus, the observed increased G6PD activity could indicate phagocytosis-associated HMS stimulation and increased H₂O₂ production.

Fig. 1 Comparative splenomegaly in mice infected with FLV, with or without intraperitoneal injection of sterile thioglycollate. Each point represents average spleen weight $\pm$ 1 s.e. for 12-15 mice on days 15 or 30 after infection with FLV (—) or for uninfected control mice (---), either untreated (○) or given thioglycollate (●) only.

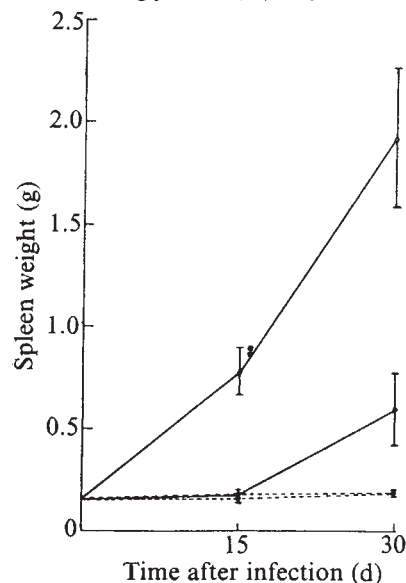


Table 1 Stimulation of glucose-6-PO₄ dehydrogenase and peroxidase activities in peritoneal exudate cells from mice treated with thioglycollate

Thioglycollate treatment*	Enzyme activity†	
	G6PD	Peroxidase
—	0.239	<0.001
+	1.352	0.158

*PE cells pooled from either normal mice or mice injected intraperitoneally 48 h earlier with 0.5 ml of thioglycollate medium.

†Average activity for 6–8 determinations; G6PD activity expressed as $\mu\text{mol NADP reduced per min per } 10^8 \text{ cells}$ and peroxidase activity as guaiacol units per 10^8 cells .

It has been reported that activated macrophages have increased HMS activity²⁸ and are more phagocytic²⁷ than control macrophages.

The marked increase of peroxidase activity in thioglycollate-induced PE cells is similar to that reported by Simmons and Karnovsky²⁸ for casein-induced PE cells. From the results of our studies one could speculate that the peroxidase-H₂O₂-halide antimicrobial system can function *in vivo* and is effective against a tumorigenic virus such as FLV. Injection of thioglycollate has also been reported to induce plasminogen activator activity in PE cells²⁹.

We have noted a possible relationship between G6PD and peroxidase activities of thioglycollate-induced PE macrophages and suppression of FLV-leukaemogenesis. Data from preliminary experiments indicate that injection of thioglycollate up to 6 d after FLV infection significantly ($P<0.01$) reduces splenomegaly and that spleens from thioglycollate-treated FLV-infected mice contain less than 1% of virus assayed in untreated, infected mouse spleen cells. These results tend to show that thioglycollate treatment affects both the virus and newly transformed tumour cells.

Table 2 Suppressive effect of thioglycollate treatment of mice on FLV induced immunosuppression to SRBC.

Mouse group*	Thioglycollate treatment†	Haemolytic PFC‡	
		Per spleen	Per 10^6 spleen cells
Control	—	68,350	441.7
	+	30,117	283.8
FLV-infected	—	1,359	10.4
	+	20,083	141.7

*Groups of mice, either normal or FLV infected, challenged intraperitoneally with 0.5 ml of 2% SRBC suspension.

†Treated mice given 0.5 ml of thioglycollate intraperitoneally.

‡Average number of PFC for 6–8 spleens for indicated mouse group 4 d after challenge immunisation with SRBC.

Activated macrophage peroxidase and G6PD activity could be involved in the observed inhibition of leukaemogenesis because the peroxidase-H₂O₂-halide system has been shown to have both virucidal¹⁹ and anti-tumour effects^{30–32} *in vitro*. It has been reported that thioglycollate-induced macrophages do not exhibit anti-tumour cell activity *in vitro*^{33–35}. It has been shown, however, that mouse lymphoma cells exposed to $5 \times 10^6 \text{ M H}_2\text{O}_2$ for 60 min *in vitro* do not show changes in ⁵¹Cr release, trypan blue uptake or ¹⁴C-glucose oxidation but they no longer are able to induce tumours in susceptible mice³². Thus there may or may not be a relationship between *in vitro* and *in vivo* effects on a given parameter. Since the peroxidase-H₂O₂-halide antimicrobial system has been shown to have *in vitro* anti-tumour effects and injection of thioglycollate results in *in vivo* suppression of leukaemogenesis and elicitation of macrophages with increased peroxidase and G6PD levels, it seems that further studies of these and related metabolic activities could form the basis of a

rational approach to prevention or therapy of some forms of malignancy.

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Melatonin may be synthesised in enterochromaffin cells

MELATONIN (*N*-acetyl-5-methoxytryptamine) is a hormone, originally isolated from the epiphysis of the bull¹, which is synthesised from 5-hydroxytryptamine (5-HT). Since the main site of synthesis of 5-HT is in the enterochromaffin cells of the intestinal tract² we investigated the possibility that melatonin is also formed there. We have found evidence in favour of this possibility.

Mucosa of human appendices was homogenised in saline and an alkaline extract was prepared as described previously³. The effect of the extract on frog skin melanophores was compared with the effects of 5-HT, melatonin, adrenaline and hydrocortisone. Each substance was administered into the lymphatic sac of frogs on five occasions, and in each substance we incubated pieces of skin taken from backs of ten normal frogs. Results were assessed by colour changes of skin^{4,5} (50–60 melanophores in a microscope visual field magnified 56 times).

After incubation for 15–20 min, the mucosal extract produced changes in the frog's skin, consisting of an aggregation of pigment granules in the centre of cells around the nucleus, together with a change in shape of the melanophores, which assumed a compact, rounded form. There followed a gradual clarification of the melanophores, characteristic of the effect of melatonin. After 4–5 h the clarification became visible to the naked eye in as much as the outline of the pigmented areas became indistinct (Fig. 1). Solutions of adrenaline (0.1%), hydrocortisone (0.2%) and 5-HT (1%) did not clarify melanophores in the same period of time, although a solution of

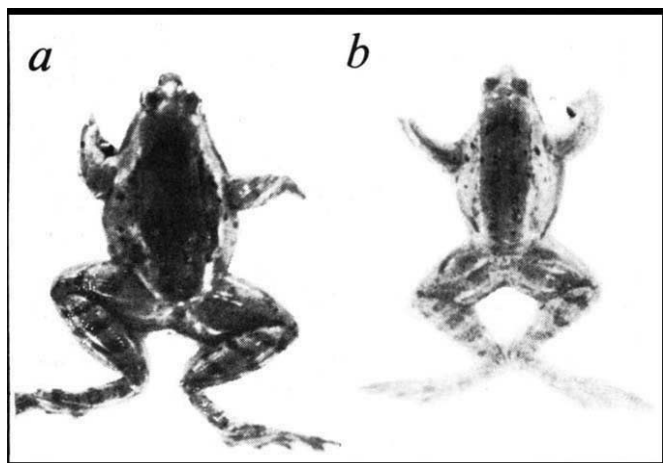


Fig. 1 Effect of alkaline extract of mucosa from human appendices on the melanophores of frog skin. *a*, Untreated skin; *b*, 5 h after administration of extract into the lymphatic sac.

melatonin (0.006%) in ethanol (30%) produced an effect comparable with the mucosal extract.

Thus an extract of the mucosal lining of human appendices contains a substance with a melatonin-like action. Since no direct demonstration of melatonin synthesis in human mucosa was produced, we investigated an intestinal extract of the rabbit, an animal known to contain large numbers of enterochromaffin cells. Thin-layer chromatography showed the presence of melatonin (R_f 0.73), together with 5-hydroxytryptophan (R_f 0.07), 5-HT (R_f 0.11) and 5-methoxytryptamine (R_f 0.32) (Fig. 2). Paper chromatography, using Filtrak F No. 1 paper with butyl alcohol-acetic acid-water, (12:3:5) or isopropyl alcohol-ammonia-water (8:1:1) as solvents, confirmed the thin-layer chromatography data, and also revealed traces of tryptamine (R_f 0.79 in the butyl alcohol-based solvent system).

The presence of melatonin precursors in the extract suggests that melatonin is synthesised in the intestinal mucosa rather than being transported there from some other site. Since the 5-HT is synthesised in the enterochromaffin cells² it seems likely that it is these cells which contain the melatonin and that it is synthesised there. Evidence to support this was obtained by a comparison of the melanophore-clarifying effects of mucosa, containing varying numbers of enterochromaffin cells, obtained from different cases of appendicitis (Table 1).

Our findings may be interpreted as supporting the suggestion⁶ that the enterochromaffin cells, or the endocrine cells of the appendix which are producing melatonin, are derived from the neuroectoderm of the neural crest. The enterochromaffin cells

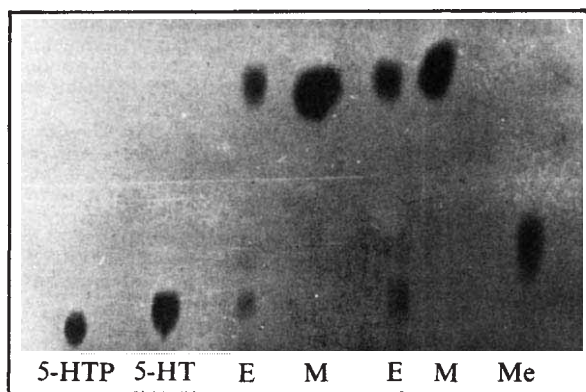


Fig. 2 Thin-layer chromatography of an alkaline extract of the intestinal mucosa of the rabbit. Chromatography was performed on Silufol UV 254 (Kavalier, Czechoslovakia) using isopropyl alcohol-benzyl alcohol-ammonia (10:5:1) as the solvent system. 5-HTP, 5-hydroxytryptophan; 5-HT, 5-hydroxytryptamine; E, extract; M, melatonin; Me, 5-methoxytryptamine.

Table 1 Time changes in clarification effect depending on the number of enterochromaffin cells in mucosal lining of appendices used in preparation of alkaline extracts

State of appendix	No. of appendices	Average number of enterochromaffin cell per crypt*	Time of clarification
Acute catarrhal appendicitis	61	4-5	25-30 min
Acute phlegmonous appendicitis	95	16-30	15-20 min
Acute gangrenous appendicitis	17	0-2	No effect

*The number of enterochromaffin cells was counted in ten sections, taken from different regions of each appendix; in each section the number of enterochromaffin cells were counted in ten crypts—thus in each appendix we counted cells in 100 crypts. The number of cells thus counted was divided by 100 to obtain the number of enterochromaffin cells per crypt.

belong to the amine precursor uptake and decarboxylation series of endocrine peptide-producing cells⁷ which have been described as constituting a peripheral neuroendocrine system, analogous to the central neuroendocrine system of the hypothalamus⁸.

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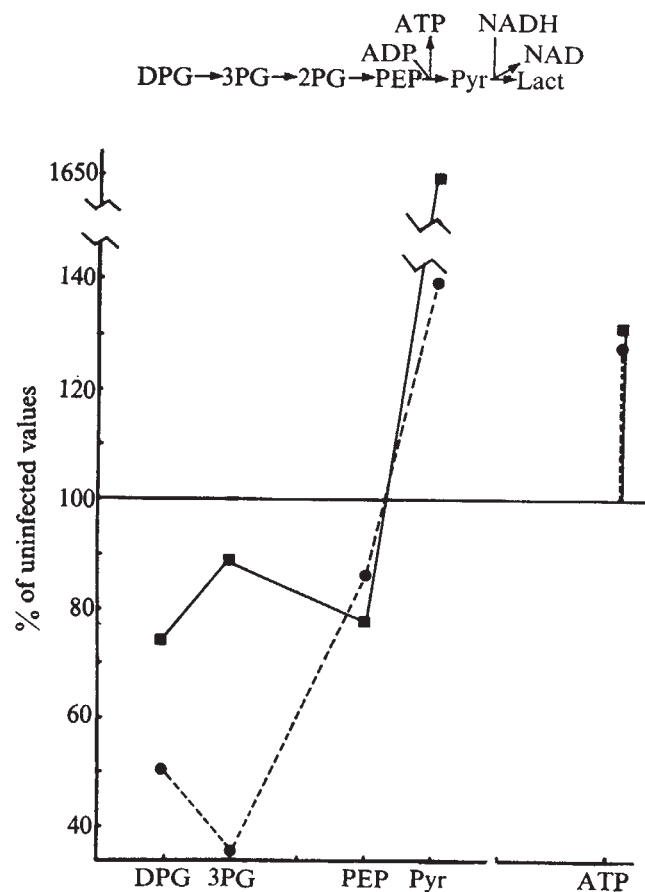
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Pyruvate kinase in malaria host-parasite interaction

THE mammalian malaria host-parasite systems seem particularly useful for studies aimed at elucidating the biochemical mechanisms of such interactions. During the vertebrate phase of their life cycles the malaria organisms are intracellular parasites of the red cell. The mature mammalian host red cell is also relatively simple metabolically; its energy metabolism is solely that of Embden-Meyerhof glycolysis and it also lacks the capacity for protein synthesis. We therefore studied several aspects of red cell glycolysis in monkeys heavily infected with *Plasmodium knowlesi* and mice heavily infected with *P. berghei*. In both these systems we have found an increase in red blood cell adenosine triphosphate (ATP) and a decrease in red cell 2,3-diphosphoglycerate (DPG). We also have evidence that these malaria parasites introduce a pyruvate kinase isozyme into their host red cells in amounts sufficient to alter red cell glycolysis. First, glycolytic intermediate data demonstrate an *in vivo* increase in pyruvate kinase activity in infected red cells; second, there is an increase in pyruvate kinase V_{max} activity in infected cells; and third, gel electrophoretic patterns show a new pyruvate kinase isozyme in infected cells. We suggest that this alteration in red cell glycolysis is in a direction favourable



to the parasite because it will increase red cell ATP at the expense of red cell DPG.

Figure 1 summarises the glycolytic intermediate data in the form of glycolytic plots for the monkey-*P. knowlesi* and the mouse-*P. berghei* systems. The assay and extraction procedures have been described previously¹. Glycolytic plots are subject

Fig. 1 Glycolytic plots of malaria-infected red cells. —, Glycolytic plot obtained using values on four rhesus monkeys heavily infected with *P. knowlesi* (an average of 40% of red cells infected). The glycolytic intermediates are listed on the horizontal axis in their order of appearance in the glycolytic pathway. For each monkey the level of each intermediate is expressed as a ratio (%) of the monkey's preinfected level. The average percentage for all four monkeys is then plotted to give the solid line in the figure. Control monkeys, similarly bled and treated (including one bled to the same degree of anaemia as his counterpart)—but not infected—do not give this pattern. -----, Comparison of the intermediate levels obtained from the pooled blood of three *P. berghei* infected mice (64% of red cells infected) with the pooled blood obtained from three healthy mice. The small blood volumes obtainable did not enable us to assay the same mice both before and after infection as was done with the monkey. The extraction and assay procedures have been described previously¹.

to variable interpretations and in considering such plots it is useful to know whether glucose consumption has increased or decreased. We have found a 7.5-fold and a 12-fold increase in glucose consumption in *P. knowlesi*-infected monkey red cells (34% infected) and in *P. berghei*-infected mouse red cells (38% infected) respectively. (Similar glucose consumption data abounds in the malaria literature.) With these considerations the simplest interpretation of the glycolytic plots of Fig. 1 is that malaria infection leads to an increase in the *in vivo* activity of pyruvate kinase. Such an increase would lead to a decreased steady-state level of phospho-enol pyruvate (PEP) and preceding intermediates (Fig. 1). The increase in pyruvate and lactate seen in the plots would also be consistent with increased pyruvate kinase activity but since these two intermediates can pass through the red cell membrane (unlike PEP and preceding intermediates) and can arise from other sources (such as muscle), the levels of these two intermediates may not be as directly associated with red cell glycolysis. We and others have previously found that an increase in *in vivo* pyruvate kinase activity does lead to patterns similar to those seen in Fig. 1 including the decreased 2,3-DPG and increased ATP^{2,3}. The mechanism by which these changes occur has been discussed previously³.

Table 1 summarises the increases in pyruvate kinase activity (V_{max}) we have seen in malaria infected blood haemolysates. Clearly, enzyme activity is increased in infected blood. The

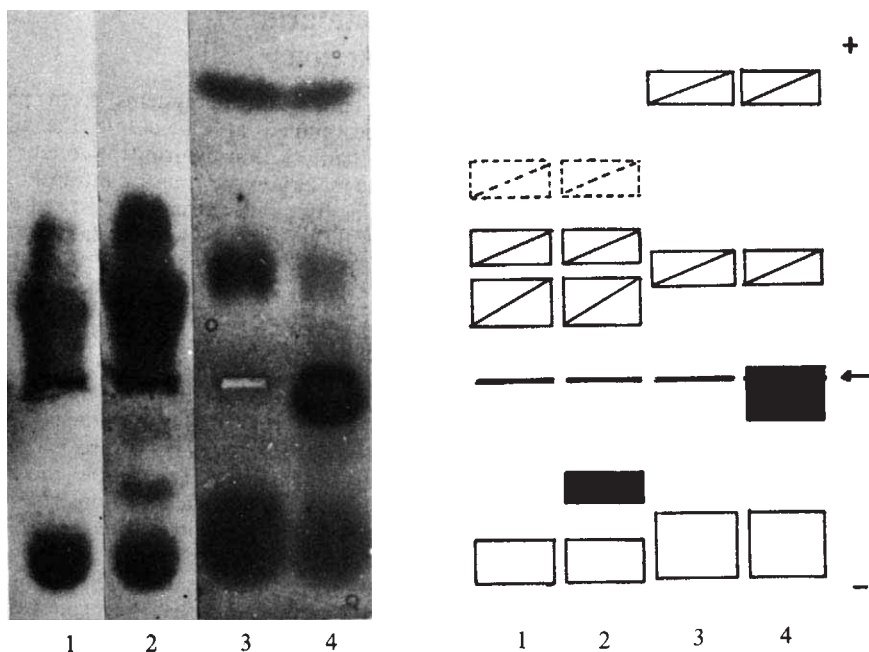


Fig. 2 Starch gel electrophoretic study of pyruvate kinase isozymes found in malaria-infected and uninfected blood samples. The adenylate kinase bands were discerned by staining the opposite face of the gel. This is necessary since the pyruvate kinase stain also stains for adenylate kinase⁵. In the diagram the dark bands are those which stained for pyruvate kinase activity only, the lined bands stained for adenylate kinase, whereas the open bands are haemoglobin bands. The dashed lines represent faint bands which are difficult to see in the photograph. Slot 1, uninfected monkey haemolysate; Slot 2, infected monkey haemolysate; Slot 3, uninfected mouse haemolysate; Slot 4, infected mouse haemolysate. In both the malaria infected mouse and monkey bloods a new pyruvate kinase isozyme can be seen. Presumably, as with human haemolysates, the uninfected mouse and uninfected monkey red cell pyruvate kinase activities are buried within the adenylate kinase area⁵.

Table 1 Increase in pyruvate kinase $V_{\max}$ activity in malaria-infected red cells

Monkey- <i>P. knowlesi</i> system	% Parasitaemia*	% of Uninfected†
I	54	192
II	46	130
III	34	122
IV	26	119
Mouse- <i>P. berghei</i> system		
I	> 80	244
II	> 80	480
III	51	236

*% red cells containing parasite(s).

†Calculated as; $100 \times (\text{Infected } V_{\max})/(\text{Uninfected } V_{\max})$.

Uninfected values are the same types as discussed in Fig. 1. The four control monkeys of the above experiments showed no or little increase (103%) in pyruvate kinase activity.

pyruvate kinase assay was performed on lysates of red cells washed three times in saline with the buffy coat removed at each washing⁴. Activity was calculated on a per gram haemoglobin basis.

Figure 2 illustrates banding patterns obtained when the above infected and uninfected red cell haemolysates were subjected to starch gel electrophoresis and stained for pyruvate kinase⁵. It can be seen that in both *P. knowlesi* and *P. berghei*-infected blood cells a new band of pyruvate kinase activity is present which was not present in uninfected blood. Presumably these new enzyme bands are of parasitic origin. (Indeed, mature mammalian red cells lack the metabolic machinery to synthesise new enzymes.)

There has been much interest in the role of ATP in malaria infections. In human volunteers inoculated with *P. falciparum* the rate of parasitaemia was directly correlated with the individual's red cell ATP value⁶. Also, in monkeys infected with *P. cynomolgi* the maximum parasitaemia correlated with red cell ATP level⁷. In *in vitro* culture ATP favours the growth of the parasite⁸. Red cell ATP levels have been shown to vary during the course of infection with the magnitude and direction of change depending, perhaps, on the host-parasite system under study and stage of parasitic development during sampling⁹⁻¹². Our studies have demonstrated an increase in ATP levels in heavily infected red blood cells for the mouse-*P. berghei* system and the monkey-*P. knowlesi* system. Pyruvate kinase is also implicated as a major determinant of this increase.

The source of ATP in the mature mammalian red cells is anaerobic glycolysis (such red cells cannot carry out oxidative phosphorylation). From a teleologic (and evolutionary) viewpoint the introduction of pyruvate kinase into the red cell by the parasite is biochemically sound. Pyruvate kinase is a rate-limiting step of red cell glycolysis and a relative increase in pyruvate kinase activity is known to increase red cell ATP at the expense of DPG^{2,3}. ATP is needed and/or used by the parasite, while DPG is important for red cell oxygen transport function but presumably is of no value to the parasite (ATP and DPG are the two major intermediates in monkey and mouse red cells.)

Although our study demonstrates a role for pyruvate kinase in at least two mammalian malaria host-parasite systems, it certainly does not exclude other concurrent enzyme interactions. Certainly, the large increases in glucose consumption cannot be explained simply on the basis of a pyruvate kinase increase. Other factors most certainly must be operative. It would be interesting, however, to see if similar pyruvate kinase data exist for other host-parasite systems. One species of avian malaria also seems to have its own pyruvate kinase isozyme¹⁰. Perhaps *in vivo* pyruvate kinase perturbations are a general host-parasite phenomenon.

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NMR evidence for common tertiary structure base pairs in yeast and *E. coli* tRNA

ABOUT ten years ago Holley¹ and coworkers sequenced the first tRNA and proposed the now famous cloverleaf secondary structure. Since that time about sixty additional tRNAs have been sequenced and all fit the cloverleaf model². This homology constitutes a strong case for the cloverleaf model and there is now compelling evidence from nuclear magnetic resonance (NMR) studies³ that the cloverleaf model does provide a correct description of the secondary structure of tRNA molecules in solution.

In addition to secondary structure homologies, tRNAs also contain constant bases in single stranded regions of the cloverleaf model. The first of these homologies was pointed out by Levitt who noted that residues in positions 15 and 48 are either G₁₅-C₄₈ or A₁₅-U₄₈ (ref. 4). On this basis Levitt suggested that bases in positions 15 and 48 form a tertiary structure base pair. The accumulation of tRNA sequences since Levitt first made his proposal has shown that other homologies exist in Class I (ref. 4) (D4V5) (ref. 5) tRNA, including A₁₅-U₈ (S'U₈), G₁₉-C₅₆ and A₅₈-T₅₄ (refs 4-6) and hence these too may be involved in tertiary structure base pairs.

In the light of these observations we are interested in the possibility of detecting the presence of additional base pairs beyond those predicted by the cloverleaf model and have recently shown that an anomalous 14.8 p.p.m. resonance which occurs in the low field NMR spectra of many *Escherichia coli* tRNAs is a result of a common homologous tertiary structure base between A₁₄ and S'U₈ (refs 7 and 8). The fact that we were able to identify unequivocally a resonance from one tertiary structure base pair suggested that it might be possible to observe resonances from other tertiary structure base pairs.

To test the proposal that most Class I tRNAs contain an identical set of tertiary structure base pairs, we have examined the low field NMR spectra of unfractionated *E. coli* and yeast tRNA at several different temperatures with and without magnesium. The idea behind these experiments was quite simple. Since the proposed tertiary base pairs are the same or nearly the same in all Class I tRNA they should give rise to relatively sharp resonances and thus should stand out above the broad background of unresolved overlapping resonances from secondary structure base pairs. Furthermore, resonances from tertiary structure base pairs should be more temperature sensitive than secondary structure base pairs. The NMR spectra of unfractionated *E. coli* and yeast tRNA are shown in Figs 1 and 2 and they do exhibit several sharp resonances in the low field region. To determine whether or not these resonances correspond to tertiary structure base pairs, the effect of salt and tem-

Table 1 Comparison of the homologous bases in *E. coli* and yeast tRNA

	<i>E. coli</i> Class I (D4V5)	All	Yeast Class I (D4V5)	All
8-14	S ⁴ U-A (12/13) U-A (1/13)	S ⁴ U-A (16/21) U-A (5/21)	U-A (7/8) U-G (1/8)	U-A (13/14) U-G (1/14)
19-56	G-C (13/13)	G-C (21/21)	G-C (8/8)	G-C (14/14)
15-48	G-C (11/13) A-U (2/13)	G-C (15/21) A-U (5/21)	G-C (2/8) A-U (3/8) G-m ⁵ C (2/8) U-C (1/8)	G-C (3/11) A-U (4/11) G-m ⁵ C (3/11) U-C (1/11)
54-58	A-T (13/13)	A-T (21/21)	A-T (2/8) m ¹ A-T (6/8)	A-T (6/14) m ¹ A-T (8/14)
9-12-23*	A-U-A (12/13) G-C-G (1/13)	—————	A-U-A (2/8) m ¹ G-C-G (4/8) m ¹ G-U-A (2/8)	—————
13-22-46*	C-G-M ⁷ G (12/13) C-G-A (1/13)	—————	C-G-m ⁷ G (4/8) C-G-G (2/8) Ψ-A-m ¹ G (1/8) U-A-A (1/8)	—————

The numbering system is that of yeast tRNA^{Phe}. Sequence data were obtained from ref. 2. Sequences included in Class I (D4V5) are for *E. coli*; Arg, Asp₁, Gly₃, His₁, Ile₁, Met₁, Met_m, Phe, Trp, Val₁, Val_{2a} and Val_{2b} and for yeast; Ala, Arg₃, Gly₁, Lys₁, Lys₂, Met₁, Phe and Trp.

* Those tRNAs which are not Class I do not exhibit homology in the base triples 9-12-23 and 13-22-46.

perature on the spectra were investigated.

The spectra presented in Fig. 1 clearly show that magnesium has a pronounced effect on the low field spectrum of unfractionated *E. coli* tRNA. The difference in the spectrum with and without magnesium at 50 °C shows pronounced peaks at 13.8, 13.0 and 11.8 p.p.m. The most striking feature of the difference spectrum in Fig. 1 is its sharpness. This indicates that there is a magnesium effect on the tRNA structure and that the change is the same for most or all of the tRNAs. In light of the variability in the secondary structure base pairs it would seem that a common change in secondary structure of all tRNA cannot be responsible for this effect. Integration of the peaks in

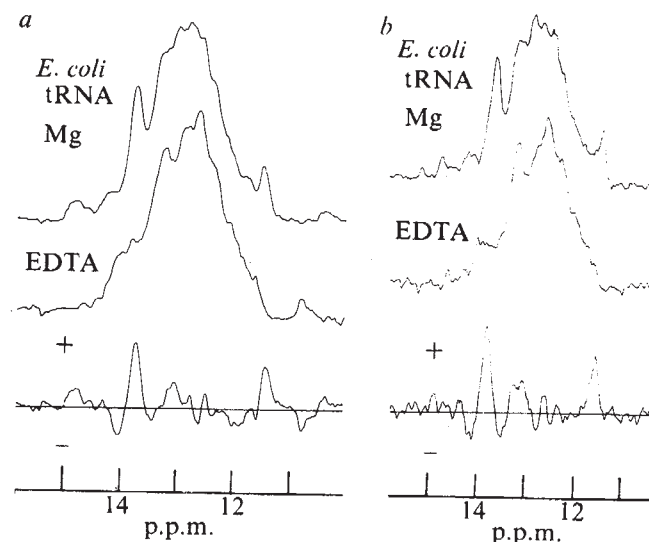
the difference spectrum shows that the amount of change increases from 24 to 50 °C, such that at 50 °C the intensity of each of the three main peaks in the difference spectrum corresponds to about 0.9 protons (assuming the intensity of the low field spectrum in the presence of magnesium corresponds to 22 protons per molecule) (determined by comparison of the integrated intensity of the aromatic and low-field resonances in H₂O and D₂O). The two main conclusions to be drawn from these data are that the spectral changes arise from base pairs which are common to most or all tRNA and that these are the weakest base pairs in the structure.

The behaviour of unfractionated yeast tRNA is basically the same as *E. coli* tRNA (see Fig. 2) although the peaks in the difference spectra are not as sharp as in *E. coli*. This is probably a result of the greater variance in the homologous base pairs as indicated in Table 1. To check the overall intensity change induced by the magnesium we measured the spectrum of a sample with magnesium and then again after the EDTA had been added to remove the magnesium. The sample was strongly buffered to eliminate pH changes resulting from the EDTA addition and all spectra were taken with identical instrument settings. Comparison of the two spectra showed a slight loss of intensity 2 ± 1 produced by the removal of the magnesium at 40 °C. The uncertainty in the net loss introduces a slight uncertainty as to where the base line of the difference spectrum is to be drawn, but does not affect the appearance of the sharp differences which are observed.

The peaks in the difference spectrum share two important characteristics which indicate that they should be attributed to tertiary structure base pairs: first, common resonance positions in the low field spectrum indicating they correspond to base pairs which are common to most of the tRNA, and second, early melting indicating they are the weakest base pairs in the molecule. On the basis of position and intensity, we tentatively assign the peak in the difference spectrum at 13.8 p.p.m. to the invariant A-T base pair in the TΨC loop and the peak at 13.0 p.p.m. is assigned to the invariant G₁₉-C₃₈ base pair. These assignments are consistent with the ring current shift parameters⁹ which we have successfully used to interpret the low field resonances arising from secondary structure base pairs and with other factors discussed below. The peak at 11.8 is assigned to a common G₂₂-C₁₃ secondary structure base pair and broadening of this resonance results from the loss of tertiary structure and unstacking of A₁₄ from G₂₂-C₁₃.

We also considered assigning the difference spectrum to

Fig. 1 All spectra were measured at 300 MHz with a Varian HR300 spectrometer operated in the field sweep mode. The signal from the spectrometer was averaged by a Nicolet 1020A computer. The temperature was controlled to ± 1 °C during the course of an experiment. Positions are in p.p.m. downfield from 2,2-dimethyl-silapentane-5-sulphonate (DSS). *E. coli* unfractionated tRNA was obtained from Plenum Scientific (Lot 74121). The samples were prepared by dialysis against 0.1 M NaCl, 10 mM cacodylate pH 7.0 and 2 mM EDTA. The tRNA concentration was 35 mg ml⁻¹ in a sample volume of 10 μl. *a*, NMR spectra of *E. coli* unfractionated tRNA at 40 °C with Mg (Mg) and without (EDTA). The difference spectrum is that of the sample containing magnesium minus the one containing EDTA. *b*, NMR spectra of *E. coli* unfractionated tRNA at 50 °C with Mg (Mg) and without (EDTA). The difference spectrum is calculated as in *a*.



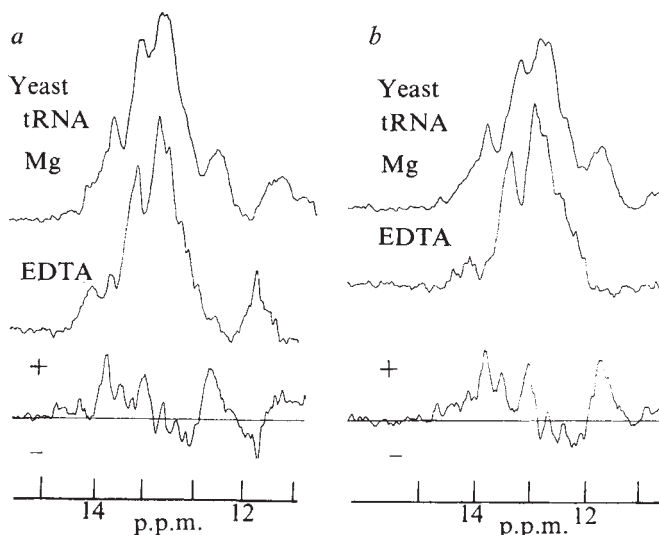


Fig. 2 The spectra were obtained and the sample prepared as described in Fig. 1. Yeast unfractionated tRNA was obtained from Plenum Scientific (Lot 72041). *a*, NMR spectra of yeast unfractionated tRNA at 40 °C with Mg (Mg) and without (EDTA). The difference spectrum is that of the sample containing magnesium minus that of the one containing EDTA. *b*, NMR spectrum of yeast unfractionated tRNA at 50 °C with Mg (Mg) and without (EDTA). The difference spectrum is calculated as in *a*.

loss of the DHU stem since it too is highly homologous in Class I tRNA and is expected to be the weakest secondary structure helix in the molecule. Such an assignment seems unlikely, however, for the following reasons. First, the intensity distribution of the difference spectrum (with the exception of G₂₂-C₁₃) does not fit that predicted by ring current calculations on the DHU stem. Second, we have observed that tRNA fragments containing the DHU stem do not melt in the absence of magnesium until above 50 °C (B. R. Rordoff and D. R. Kearns, in preparation). Third, only about 50–60% of the *E. coli* tRNA have appropriate DHU stem sequences whereas the intensity loss at 13.8 corresponds to one resonance per molecule. Finally, the NMR spectra of various other pure tRNAs (*E. coli* tRNA^{Arg}, Val¹, Phe, Asp¹ and yeast tRNA^{Phe} and others) exhibit anomalously high intensity at 13.8 p.p.m. the position where the intensity in the difference spectrum in the unfractionated tRNA is greatest. On the basis of these and other observations to be described elsewhere, we conclude that two of the main features observed in the *E. coli* and in the yeast difference spectra (magnesium minus no magnesium) correspond to tertiary structure base pairs. These results, taken with our earlier studies of the base pairing involving S⁴U₈ indicate that there are at least three tertiary structure base pairs present in tRNA in solution. If our proposed assignments are correct, these would correspond to three of the same tertiary base pairs which have been proposed on the basis of X-ray diffraction studies of yeast tRNA^{Phe} (refs 10 and 11). It would also seem that the tertiary structure base pairing and hence the tertiary structure of most *E. coli* as well as yeast tRNA are nearly identical. This provides strong justification for generalising features observed for one Class I (D4V5) tRNA to others.

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Ultraviolet inducible protein associated with error prone repair in *E. coli* B

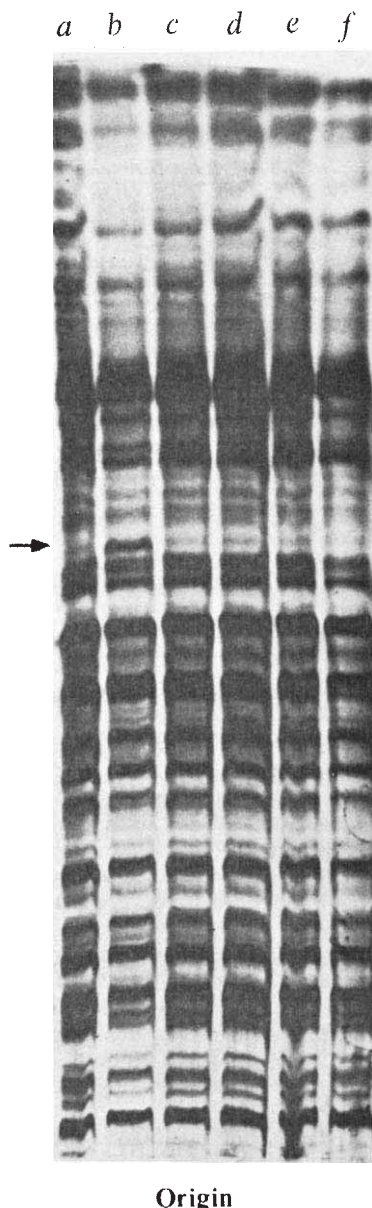
Escherichia coli is affected in many ways by irradiation with ultraviolet light. New DNA is made containing gaps resulting from synthesis on damaged templates^{1,2} and postreplication repair seals them by exchanging sections of DNA between daughter duplexes^{3,4}. The induction of mutations by ultraviolet light has been attributed to errors occurring during this type of repair^{5–7} and so this repair has been called error prone. Ultraviolet radiation also results in prophage induction⁸, inhibition of respiration⁹, filamentous growth¹⁰ and the development of extra capacity to promote the survival¹¹ and mutagenesis¹² of irradiated infecting phages. All these events require the *recA*⁺ and *exr*⁺ genes^{2,7,9,13–23} but the ways in which *recA*⁺ and *exr*⁺ gene products affect such a diversity of postirradiation events are not known. One proposal is that they act in a single molecular process which in some way initiates all the phenomena described above and that the *recA*⁺ *exr*⁺ dependent functions are inducible²³ by ultraviolet light and thus require the synthesis of new protein(s) in irradiated bacteria. Here I demonstrate that *E. coli* does indeed synthesise a protein in response to ultraviolet irradiation and that the synthesis of this protein is dependent on *exr*⁺ and *recA*⁺ genes.

Cultures of *E. coli* strains WP2_s *uvrA* *trp*²⁴, and its conjugal or transductional derivatives WP100 *uvrA* *recA* *trp* and CM611 *uvrA* *exrA* *trp*²⁵ were grown overnight, diluted 100-fold into Bacto Davis minimal medium supplemented with tryptophan (20 µg ml⁻¹) and grown to cell densities of about 10⁸ per ml. The proteins synthesised in unirradiated and ultraviolet-irradiated bacteria were labelled for 20 min by the addition of 2 µCi of ³⁵S-methionine (specific activity 149 Ci mmol⁻¹ obtained from New England Nuclear Corp.) and 0.02 µg of methionine to 0.1 ml aliquots of culture. The cells were pelleted, lysed in 25 µl of 0.05 M Tris-HCl (pH 6.8), 1% sodium dodecyl sulphate, 1% mercaptoethanol, 0.002 M EDTA, 10% glycerol and 0.025% Coomassie blue and heated in a boiling water bath for 2 min. This treatment causes protein denaturation and dissociation, giving a preparation of unassociated individual proteins and protein subunits of multimeric molecules.

The proteins were analysed by electrophoresis through 10% polyacrylamide gels containing 0.26% N,N'-methylene bis acrylamide, 0.19 M Tris-HCl (pH 8.8), 0.1% sodium dodecyl sulphate, 0.002 M EDTA. The electrode buffer contained 0.05 M Tris, 0.38 M glycine, 0.1% sodium dodecyl sulphate and 0.002 M EDTA. Electrophoresis was for 75 min at 200 V using the apparatus and procedure described by Studier²⁶. Autoradiograms of dehydrated gels were made using Kodak SB54 X-ray film. A typical autoradiogram is shown in Fig. 1.

Columns *a*, *c* and *e* show the identical distributions of proteins from unirradiated strains WP2_s *uvrA*, WP100 *uvrA* *recA* and CM611 *uvrA* *exrA*, respectively. An ultraviolet dose of 4.8 J m⁻² to WP2_s specifically induced the synthesis of the protein indicated by the arrow in column *b*. There was no induction of this protein in irradiated bacteria lacking either *recA*⁺ (column *d*) or *exr*⁺ (column *f*) genes. The overall pattern of other proteins in all the strains was not influenced by ultraviolet radiation.

The phenomena induced by ultraviolet radiation were also induced after incubating bacteria with the *tif* mutation at 42 °C^{7,27–29}. The proteins of the strain WP44_s-NF *uvrA*



Origin

Fig. 1 Proteins made in unirradiated and ultraviolet-irradiated *E. coli*. Proteins were radioactively labelled with ^{35}S -methionine and analysed by electrophoresis through 10% polyacrylamide as described in the text. The proteins shown are from strains: *a*, WP2_s *uvrA*, no ultraviolet; *b*, WP2_s *uvrA*, 4.8 J m⁻² ultraviolet; *c*, WP100 *uvrA recA*, no ultraviolet; *d*, WP100 *uvrA recA*, 4.8 J m⁻² ultraviolet; *e*, CM611 *uvrA exrA*, no ultraviolet; and *f*, CM611 *uvrA exrA*, 4.8 J m⁻² ultraviolet. The arrow indicates the position of a protein band only present in irradiated *E. coli* WP2_s *uvrA*.

tif were analysed after growth at inducing, 42 °C, or non-inducing 30 °C temperatures. Incubation at 42 °C increased synthesis of the same new protein seen in irradiated *E. coli* WP2_s *uvrA*.

I conclude that events such as error prone repair and filamentation are inducible because they are caused by the activity of *recA*⁺ and *exr*⁺ genes, which are shown here to allow the induced synthesis of a specific new protein in irradiated cells.

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Histones in fixed cytological preparations of Chinese hamster chromosomes demonstrated by immunofluorescence

HISTONES and DNA make up the bulk of the chromosomal material and are presumably present in approximately a 1 : 1 ratio. Although it is known that histone fractions elicit specific antibodies¹; a crude basic nuclear protein will bind to chromosomes²; antisera against lysine-rich histones will stain nuclei³; and purified histone antisera will bind to chromatin⁴, little is known about the distribution of histones in fixed preparations of chromosomes. We used the immunofluorescent technique to show that an antiserum prepared from the F3 histone fraction of human leukaemic lymphoblasts binds to both human and *Drosophila* salivary gland chromosomes⁵. We have now made antisera against the five major histone fractions of calf thymus and characterised them by microcomplement fixation⁶. Using selected antisera, we found that all except the F1 histone antiserum bind to acid-fixed Chinese hamster chromosomes to various degrees. Furthermore, in some preparations a pattern of transverse banding appears. We have also found that histones remaining on the chromosome after acid fixation are very firmly bound, which is necessary for the credibility of our observations.

Calf thymus histones were fractionated by the Johns^{7,8} techniques and examined by amino acid analysis and polyacrylamide gel electrophoresis⁹. Antisera were induced by dissolving 5 mg lyophilised histone fraction in water, emulsifying in an equal quantity of Freund's complete adjuvant and injecting into multiple sites on the backs of mature female New Zealand rabbits once per week for 6 weeks (Fig. 1). Many rabbits had a repeat immunisation after 2 months to raise complement fixation titre further.

Chinese hamster chromosomes (Don and Dede lines, American Type Culture Collection) were prepared by standard acid fixation using methanol-acetic acid (3 : 1). Histone antiserum binding was assessed by indirect immunofluorescence (Fig. 2). Some acid-fixed slides were treated with 0.2 N HCl for 15 min, 1, 2 and 4 h before exposure to antisera and immunofluorescence (Fig. 3).

Immunisation of rabbits with the F1, F2a1, F2a2, F2b and F3 histone fractions provided antisera with titres of 1 : 250 to 1 : 1,000 by microcomplement fixation. Antisera from all except the F3 fraction could be obtained from

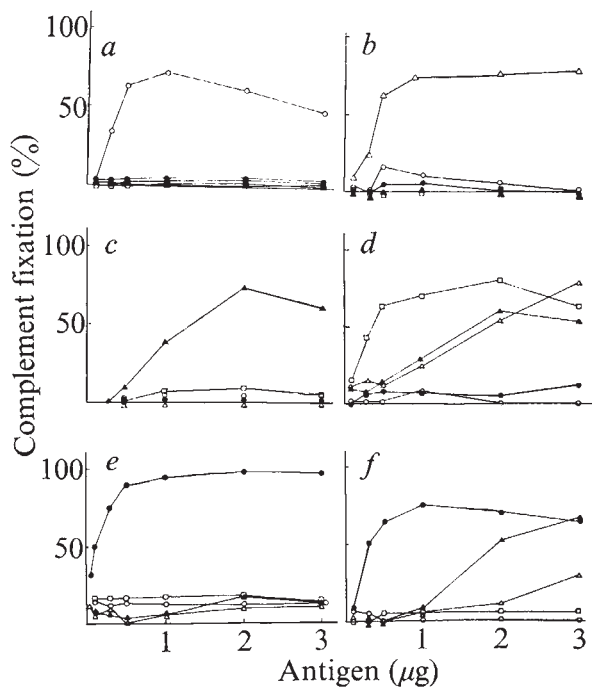


Fig. 1 Microcomplement fixation reaction of histone fractions F1 (○), F2a2 (△), F2b (▲), F3 (□) and F2a1 (●) with rabbit antisera induced by these fractions. *a*, F1 histone antiserum diluted 1:1,000; *b*, F2a2 histone antiserum diluted 1:250; *c*, F2b histone antiserum diluted 1:500; *d*, F3 histone antiserum diluted 1:1,000; *e*, F2a1 histone antiserum, 7S fraction diluted 1:50 (original titre of antiserum 1:500) and *f*, F2a1 histone antiserum diluted 1:250.

some rabbits that did not cross react with the other histone fractions (Fig. 1). In other rabbits significant cross reactivity was noted on either primary or repeated immunisation.

Antisera derived from all except the F1 histone fraction bound to the Chinese hamster chromosome. The F1 histone antiserum, although of high titre and specificity, did not bind appreciably even to bovine chromosomes. Antisera induced by the F2a1 histone fraction have been studied most extensively to date. That of Fig. 1*e* had an original titre of 1:500 and, as shown in the figure, did not cross react even when the 7S fraction of this antiserum was concentrated 1:50. The F2a1 antiserum shown in Fig. 1*f* cross reacted mainly with F2b at higher concentrations of antigen. Because the latter antiserum gave a crisper segmental pattern most preparations shown here were exposed to it. Evidence that these antisera were directed against histones comes from the fact that one or the other of them showed (1) absence of DNA antibodies by radioimmunoassay, (2) lack of species specificity, (3) absence of staining of nucleoli in interphase cells and (4) lack of staining if *Drosophila* salivary glands were incubated with 0.2 N HCl to remove histones before fixation of chromosomes (L. P., unpublished).

Distinct transverse fluorescent bands appeared on some preparations treated with F2a1-rich histone antiserum (Fig. 2). Whereas contracted chromosomes stained homogeneously and brightly, those with elongated chromatids often showed bright banded areas which increased in number with elongation. The centromere did not stain. As with traditional banding techniques, preparations were influenced by the quality and age of chromosome spreads. There was also variation in the degree and pattern of staining on a given slide. Figure 4*a-d* shows four chromosomes No. 1 from different metaphase preparations well stained with F2a1-rich histone antiserum. Figure 4*a-c* shows variations in binding but also some agreement in binding patterns in areas where chromo-

somes were similarly elongated. Figure 4*d* shows a somewhat spiral arrangement. The grouping of similarly arranged chromosomes in Fig. 4*e* and *f* is an attempt to determine whether the pattern of a chromosome well stained with non-cross-reactive F2a1 antiserum (Fig. 4*e*) resembles that of a G-banded chromosome (Fig. 4*f*). Many more such pairs must be examined before a definitive judgment can be made on resemblance to any existing banding pattern.

At a given dilution, non-cross-reactive F2a2 and F2b histone antisera did not stain as well as F2a1 antisera. Banding was fainter with the former whereas the latter created a more general, softer pattern. The highly cross-reactive F3 histone antiserum gave a brilliant banding pattern. Whereas F2a1 and F3 antisera could be used satisfactorily at a 1:48–1:72 dilution, F2a2 and F2b antisera stained best at a 1:12 dilution. F1 antisera demonstrated little or no fluorescence even at 1:6.

Incubation with 0.2 N HCl before immunofluorescence with the F2a1-rich histone antiserum decreased the intensity of overall fluorescence slightly. After 15 min, detail was blurred and by 4 h a somewhat sharper banding pattern emerged (Fig. 3).

There is much speculation about the effects of acid fixation on the presence of histones on chromosomes. Estimates of removal range from 7 up to 8% of histones from chromatin preparations (predominantly F2a1 and some F2a2 and F3)¹⁰ to 80% of histones from interphase cells (leaving F1 and F2b)¹¹ to some of all histones from nuclei¹². But these previous studies involved chromatin or interphase nuclei, rather than metaphase chromosomes to which histones bind much more firmly¹³.

Our finding that antisera against four of the five major histone fractions all bound to some degree to the chromosome suggest that there is a significant amount and variety of histones left on the chromosome after acid fixation. The F2a1-rich histone antiserum, studied in the greatest detail so far, gave especially brilliant transverse bands on some metaphase preparations. The non-cross-reactive F2a1 anti-

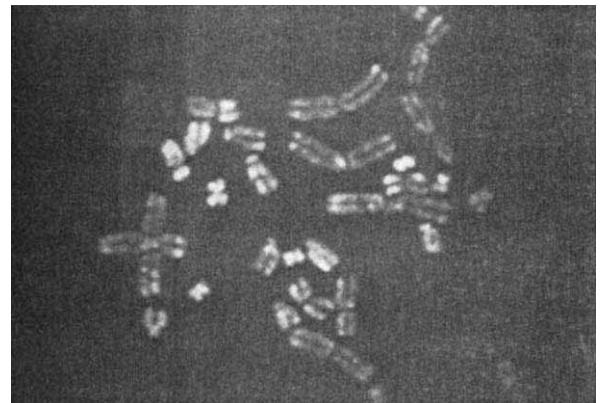


Fig. 2 Chinese hamster chromosomes prepared by standard acid fixation and stained by indirect immunofluorescence using F2a1-rich antiserum (1:24) and rhodamine-conjugated IgG fraction of goat anti-rabbit gamma globulin 1:30 (Cappel Laboratories). Chromosomes were fixed with methanol-acetic acid (3:1) and air dried on slides after exposure for a brief period on a warming plate. They were stored for short periods at 4 °C. The immunofluorescent reaction was as follows. Slides were flooded with antiserum against the histone fraction to be studied, incubated in a humid chamber at 37 °C for 30 min and rinsed with phosphate-buffered saline (PBS). After air drying, the slides were flooded with either rhodamine-conjugated IgG fraction of goat anti-rabbit gamma globulin (Cappel Laboratories) or fluorescein-conjugated antibody globulin to rabbit 7S gamma globulin (Hyland Laboratories). Both conjugates were satisfactory at a 1:30 dilution. Incubation was as above, followed by PBS rinsing and air drying. Slides were then viewed in the Leitz Ortholux microscope equipped with the fluorescence vertical illuminator with appropriate filters for fluorescein or rhodamine.

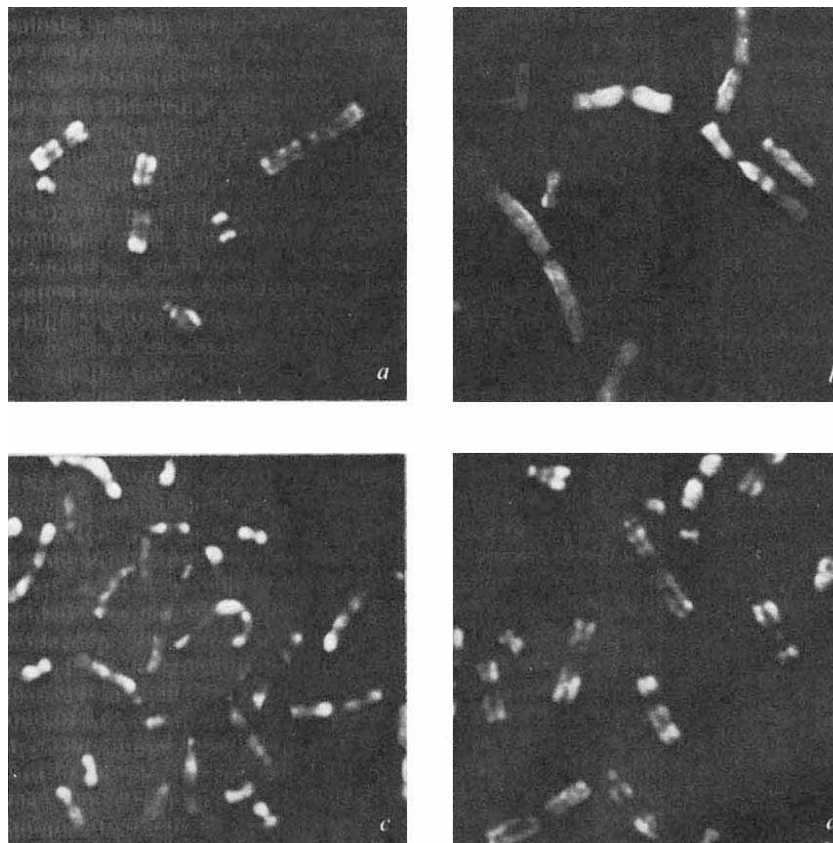


Fig. 3 The effect on immunofluorescent reaction with F2a1-rich histone antiserum of prior treatment of chromosomes with 0.2 N HCl for: a, 0 h (control); b, 15 min; c, 1 h; and d, 4 h. (Histone antiserum diluted 1:24 and fluorescein-conjugated antibody globulin to rabbit 7S gamma globulin diluted 1:20.) All photographs were taken with an exposure of 15 s and from one experiment using the same batch of chromosomes.

serum stained similarly though less intensely. The weaker staining characteristics of F2a2 and F2b antisera may be more a reflection of the antigenicity of the histone fraction than the quantity of histone on the chromosome. The strong staining of F3 antiserum may be in part a manifestation of its cross-reactivity with the other histone fractions. The finding that bovine chromosome preparations could not improve the binding of the F1 histone antiserum suggests that this lack of binding was not caused by the inherent species specificity of this histone fraction, but rather to removal of F1 histone by acid fixation. This is likely since this fraction is easily removed by certain extraction procedures¹⁴. Of course, availability of binding sites of the various histone species on the chromosome as determined by steric factors, conformational changes or binding to other proteins will affect binding of all the antisera.

Acid-fixed chromosomes incubated with 0.2 N HCl for 4 h can still be Giemsa banded¹², and so it has been concluded that histones are not involved in banding, for the 0.2 N HCl extraction procedure reputedly removes all histones. Our

finding that, after prior acid fixation of chromosomes, treatment with 0.2 N HCl for 4 h will not markedly reduce the immunofluorescent reaction with an antiserum against the F2a1 histone, suggests, however, that histones are not completely removed by this procedure. Whether histone binding will indeed relate to any specific banding pattern is unknown at present. But since a certain amount of histone is firmly bound to the chromosome by acid fixation, histones may modify banding patterns. It is more important that observation of the binding sites of histone antisera directly on the intact chromosome should yield useful information about the spatial relationship of histone to DNA and the role of the various histone fractions in chromosome structure and function.

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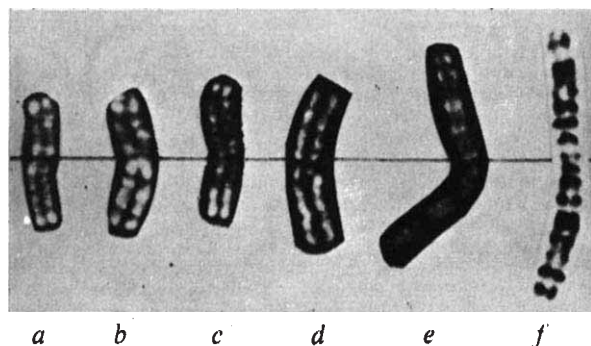
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Fig. 4 Chinese hamster chromosome No. 1 selected from various acid-fixed metaphase preparations. a, b, c, d, e, Stained with antisera made against the F2a1 histone fraction using the immunofluorescent technique and (f) stained with the Giemsa banding technique (see text).



reviews

For many years Professor Boucot has been both an indefatigable collector of Silurian and Devonian brachiopods over the whole world, and an equally energetic taxonomist. The vast amount of information he has compiled is summarised in this book which also includes a valuable survey of the important work on Palaeozoic marine invertebrate communities undertaken during the last decade by palaeontologists on both sides of the Atlantic.

It is anything, however, but a straightforward descriptive review. Right from the preface and introductory chapter Boucot plunges into his principal theme, which is basically simple: as is well exemplified by his brachiopods (though that principle is clearly thought to be of more general validity) evolution was most rapid when potentially interbreeding populations were small in size. Although other controls on rates of evolution are conceded they are dismissed as of relatively minor importance. In the course of his argument, by marshalling a wide array of facts, Boucot launches penetrating criticisms against hypotheses conflicting with his own, such as the Bretsky-Lorenz hypothesis which postulates an inverse relationship between rate of evolution and broad environmental tolerance (and genetic variability); and weaknesses in the widely accepted stability-time hypothesis of Sanders are also pointed out.

What then are we to make of Boucot's own hypothesis? Although it seems reasonable biologically, one is faced directly with the shortcoming of the method used to assess the population size of a given taxon, which is to

Extended view of evolution

A. Hallam

Evolution and Extinction Rate Controls. (Developments in Palaeontology and Stratigraphy, vol. 1.) By Arthur J. Boucot. Pp. xv+425. (Elsevier Scientific: Amsterdam, Oxford and New York, 1975.) Dfl. 110; \$42.50.

estimate the area of distribution. It is not obvious to me that there should be such a simple correlation. Again, Boucot argues that cosmopolitan taxa evolved more slowly than provincial taxa because they had larger populations. Why could not that reflect simply the greater tolerance of the cosmopolitans, which were able to survive the minor environmental vicissitudes that evidently proved too rigorous for the provincials? When Boucot generalises he is forced to indulge in special pleading. Consider, for instance, the following highly dubious and unsupported statement on page 114: "The Mesozoic ammonoids . . . exploded into a tremendous development of both taxa and individuals during several post-Palaeozoic intervals that are consistent with the concept of population size being inversely related to rate of evolution." Mammals evidently evolved faster than invertebrates because their populations were smaller. Is there any evidence whatsoever that large mammals, with smaller populations, evolved faster than small ones? In my opinion

the fossil evidence can more plausibly be held to support quite another view: that particular groups of animals, whether mammals, ammonites, bivalves or brachiopods, had characteristic rates of evolution regardless of the size of individuals, which usually correlates inversely with population size. Stanley's view that mammals evolved faster than bivalves because they competed more intensively seems much more reasonable.

In spite of his extensive discussion of biogeography Boucot holds a curiously agnostic position on plate tectonics, which is evidently regarded as being too speculative to warrant more than the most passing mention. I agree with his view that plate tectonics fails to explain many features of Silurian-Devonian provinciality. Why should the early Devonian faunas exhibit more provincialism, for instance, than those of the late Silurian, although the continental configurations had not changed significantly in the interim? It seems reprehensible, on the other hand, that Boucot neglects to consider a Gondwanaland configuration in his discussion of the Malvinokaffric Realm, which he bases on distinctive faunas occurring only in New Zealand, South Africa and southern South America.

A final comment on this interesting and provocative work concerns the rambling and verbose style of prose. If he had organised his material better and avoided the numerous repetitions he could have condensed his book into about half the length, thereby bringing the cost down to a level within the reach of individuals as opposed to institutions. □

THIS introduction to artificial intelligence deals with a wider range of topics than is customary in such texts—computability, pattern recognition, heuristic problem solving, automatic theorem proving, computer perception and comprehension of natural language. A newcomer who wants to know, for example, what an augmented transition network for the analysis of language is, or what inference by resolution means, would get some idea from this book.

But, alas, much of the exposition is neither clear nor correct. Explanations using *non-sequiturs* are particularly depressing, and inadequate diagrams obscure rather than

Intelligence book

Bernard Meltzer

Artificial Intelligence. (Academic Press Series in Cognition and Perception.) By Earl B. Hunt. Pp. xii+468. (Academic: New York and London, January 1975.) \$29.00; £13.90.

illuminate them. The account of the work of Guzman, Clowes, Huffman on the perception of line diagrams of polyhedral solids, and the treatment of picture interpretation generally, is particularly poor—per-

haps not so surprisingly: 24 pages are devoted to computer perception, whereas 161 consider 'classical' pattern recognition, the relevance of which to artificial intelligence is much smaller.

The treatment of theorem proving is marked by a confusion between the propositional and quantificational calculus, and little account is given of the important work on mathematical reasoning outside the resolution framework. The notions of analogy and model are confused with each other. Besides such obfuscations, the author is given to producing, out of the blue, large general judgments with little justification. □

Watch words for dilettanti

My Father's Watch. By Donald F. Holcomb and P. Morrison. Pp. xxvi+390. (Prentice-Hall: Englewood Cliffs, 1974.) \$11.50.

THIS enjoyable book was written for students having no professional interest in science. The authors have aimed at producing a book which is essentially 'core material' for a one-year course in physics for this type of student, supplemented by a sketch of a number of special topics. If one were to base a course on the book, quite a bit of flexibility could be attained by varying the emphasis placed on the topics covered—a nice feature.

Part 1 of the book—"The way things are"—starts with "Looking at the sky", goes on to discuss the measurement of length and time, geometry and the real world and concludes with a consideration of "exponential processes in nature"; in that chapter, a mathematical model for population growth is discussed alongside radioactive dating and the whole approach is novel and stimulating. Part 2 is concerned with "motion", and Part 3 with "energy". About 115 pages are devoted to the

latter topic out of a book of some 400 pages and among the special topics "energy and man" also figures, with a good general bibliography.

The authors are well known experts in presenting physics and the illustrations of the material in the book are highly original and often very beautiful. Thus, to illustrate translation symmetry we are shown the facade of the Doge's palace in Venice along with a row of Persian archers sketched from a frieze in Darius' Palace in Susa.

Finally, the title of the book—it is taken from the poem by John Ciardi. In the prologue the authors write "The Watchmaker turns out to be far more subtle than any who practice that skilled and yet rather limited trade; He is not to be found in the Watch ($\equiv$ the Universe), or even peering through the glass".

The authors have written an exceptionally fine book of its kind, which deserves success. **N. H. March**

Amino acid disorder

Heritable Disorders of Amino Acid Metabolism: Patterns of Clinical Expression and Genetic Variation. Edited by William L. Nyhan. Pp. xvii+765. (Wiley: New York and London, December 1974.) £17.25.

It is traditional in any book on inborn errors of metabolism, to preface one's remarks with reference to Garrod. There have been three phases in the discovery of disorders of amino acid metabolism. The first phase lasted from Garrod's work to the chromatographic innovations of Dent and his colleagues. The second phase was a result of the development of these paper chromatographic methods for screening for abnormal 'ninhydrin-positive' metabolites. About 1970, the rate of discovery of new 'ninhydrin-positive' compounds began to lessen and this gave way to the search for 'ninhydrin-negative' metabolites using the newer techniques of gas chromatography and gas chromatography-mass spectrometry. These techniques were responsible for the discovery of the organic acidaemias, secondary to defects of amino acid degradation. This third phase has coincided with an increasing recognition of genetic heterogeneity of inborn errors of metabolism; with the advent of prenatal diagnosis, and the use of pharmacological doses of vitamins in the treatment of specific enzymic defects. The study of inborn errors of amino acid metabolism is now as exciting as it has ever been, and a book dedicated to advances in this field is always of interest.

This book edited by Nyhan is beauti-

fully produced with excellent contributions from many outstanding authorities. It provides, however, an illustration of the problems involved in producing a multi-author text that is balanced and up-to-date. The logistics of obtaining individual chapters from many authors ensures that such a book is out of date before it arrives at the printers. It is useful to compare this book with *Amino Acid Metabolism and its Disorders* by Scriver and Rosenberg (1973). In that volume two distinguished authors covered the whole field themselves, continually revising each chapter, so that the book contains as many current references as possible. There is little difference between these two books in the number of references dated later than 1972, although the book by Scriver and Rosenberg was published one year earlier.

A proper balance in a multi-author text is difficult to achieve. In his preface Nyhan refers to Garrod's work on alkaptonuria and albinism. A masterly review on albinism accounts for 11% of the total length of this book, whereas alkaptonuria is not mentioned again. There are two chapters on phenylketonuria and as they overlap it is difficult to see the reason for a second chapter. The two chapters on homocystinuria are, however, useful. The first is by Perry concerning 'classical' homocystinuria and the second by Mudd is an elegant description of the more recently discovered forms, especially those secondary to defects of vitamin B₁₂, and folic acid metabolism.

The lack of balance in this book is also reflected in the description of various methodologies used in clinical and experimental studies. Directions are given for establishing a screening programme for metabolic disease based on a programme in use at the University of California. No mention is made, however, of the Guthrie 'microbiological inhibition assay', a technique used throughout the world for screening for phenylketonuria. There are unnecessary directions for the chromatography of simple sugars and the diagnosis of mucopolysaccharidoses. A chapter on the analysis of radioactive amino acids contains three pages dedicated to the description of fluorescent spectra of liquid scintillators, a list of those available, and recipes for various 'cocktails' for scintillation counting.

This book is beautifully produced but lacks balance, excellent chapters existing cheek by jowl with inadequate or unnecessary material. Its expense is no doubt related to its excellent presentation. Unfortunately, it cannot be recommended as a general text although many individual contributions are of the highest quality. **D. Gompertz**

ADAS

Science Arm Annual Report 1973

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HMSO BOOKS

New aspect of old subject

Palaeoeconomy. (Second Volume of Papers in Economic Prehistory. Edited by E. S. Higgs. Pp. xiii+244. (Cambridge University Press: London, 1974.) £8.50; \$25.00.

THE first volume of *Papers in Economic Prehistory* (edited by E. S. Higgs, 1972) established the theoretical foundation for this major research project; the present volume concentrates on applications of the new methodology to field situations. For newcomers, there is a brief glossary of terms used and a justification of the general approach in a short but provocative review by Higgs and Jarman. They conclude that archaeology should now concern itself with searching for natural laws governing human behaviour, and that the primary adaptation to the environment is in the management of the household; therefore, the 'palaeoeconomic' approach to archaeology should be the most rewarding.

The remaining five papers in the volume are presented to justify this viewpoint. Wilkinson argues that 20th century studies on musk ox behaviour can be extrapolated back to predict the ways in which musk oxen could have been exploited prehistorically, and that these predictions are supported by the archaeological record. Sturdy's analysis of reindeer economies introduces a theme shared by several of the other papers: the difficulty of detecting seasonal mobility (such as transhumance) when archaeological remains recovered from sites of different seasonal activities of the same cultural group may differ as much as remains from quite unrelated cultural groups. Here, analyses of the economic potential of the territory around the archaeological sites may help by providing some indication of seasonal interdependence of areas of summer and winter grazing neither of which alone could provide year-round subsistence. Thus Barker, and Jarman and Webley, working in different parts of Italy, show that patterns of transhumance recorded in historical times probably had their roots in the seasonal migrations of Palaeolithic hunters and developed throughout the Neolithic as stock were moved between lowlands and highlands for grazing.

The two papers on Italian prehistory, and that by Dennell and Webley on Bulgaria, also show that when intensive site surveys and analyses are carried out, the usual cultural and chronological divisions (Palaeolithic, Neolithic, and so on) become rather meaningless. The studies reported here suggest more diversity within cultural

periods and also more continuity between cultural periods than has been accepted traditionally.

Appendices include a guide to methods for carrying out site catchment analysis in the field and a discussion by Vita-Finzi of "related territories" and alluvial sediments. There are many maps and figures and these have presumably helped to push the book's price into the range in which libraries will be the chief purchasers.

Barbara Pickersgill

Fowl histology

The Histology of the Fowl. By R. D. Hodges. Pp. xv+648. (Academic: London and New York, November 1974.) £13.50; \$35.00.

THE need for a comprehensive work on the histology of the fowl has been apparent for many years. With this volume Dr Hodges has not only met this requirement but has also produced a definitive text for all those engaged in teaching or research on the domestic fowl. In 10 lucidly written and authoritative chapters the author has covered all the systems of the body and has synthesised the widely scattered literature into an eminently readable form. Not content with the descriptions of others, Dr Hodges has himself painstakingly studied the fowl, tissue by tissue, and the resultant descriptions are a distillate of wide reading and critical evaluation by an experience observer.

Each chapter is based mainly on conventional microscopy and is extensively illustrated with photomicrographs and line drawings. Just a few of these fall short of the highest quality and should be replaced in subsequent editions. Electron microscope and histochemical studies are also described, carefully assessed and presented in tabular form for the convenience of the reader. Where controversy exists, as in the mode of formation of the gizzard lining, the author evaluates the evidence and offers the reader his reasoned conclusions.

The descriptions of the reproductive, blood, circulatory, lymphatic and respiratory systems are notable for their clarity and provide clear guidelines in fields where there has been much terminological confusion. They will be particularly useful to those engaged in physiological studies or research in avian diseases.

To many, not the least valuable part of this book will be the extensive lists of references to the avian histological literature which are provided at the end of each chapter. There can be little doubt that this volume will become the standard work on the histology of the fowl.

K. J. Hill

THE PHYSICAL FOUNDATION OF LANGUAGE

Exploration of a hypothesis

R. M. ALLOTT

The hypothesis explored is that, beyond the possibly natural foundation of syntax suggested by Chomsky, the sounds and meanings of words forming a major part of English vocabulary are related. Besides survey of experimental material on phonetic symbolism and examination of the adequacy of traditional etymological accounts of the origin of English vocabulary, the main theme of the book is that the natural link between sound and meaning is made apparent in gesture. A system of equivalences between component sounds of words and component elements of gestures is presented. The claim is that what has been called the 'gestural code' has been cracked (going beyond recent discussion of paralinguistic features and particularly Birdwhistell's analysis of body movements.) Evidence of a similar natural relation in other languages is also presented, manifested in striking resemblances between word-sound patterning in many languages for precepts which are sharply and uniformly defined, particularly words for parts of the body, basic features of the environment, colour-words, pronouns and demonstratives. From Blackwells or Dillons University Bookshop or direct (£3.75 plus postage) from

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Measurement of Human Resources

edited by W. T. Singleton/P. Spurgeon

Based on the NATO Conference in Lisbon, 1973, this collection of papers includes contributions from the many relevant disciplines involved in the utilisation of human resources. This volume represents the first attempt to integrate these disciplines and it is hoped that it will provide a source of reference for a wide range of research workers and practitioners in the total sphere of human resources.

1975

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—a management approach

N. G. Anderson

This book examines the function fulfilled by development departments in companies manufacturing electronic components and assemblies, and other high-technology products, and its relationship to other functions within a company.

1975

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Immunology

Lymphocyte Stimulation. By N. R. Ling and J. E. Kay. Completely revised edition. Pp. xii+398. (North Holland: Amsterdam and Oxford; American Elsevier: New York, 1975.) Dfl.110; \$42.50.

LYMPHOCYTE stimulation encompasses most of immunology; in addition, it has long served as a popular and accessible system for studying the control of cell proliferation. Thus the boom in tumour biology and the continuing popularity of immunology assure that this second edition of Ling and Kay's *Lymphocyte Stimulation* will be widely read, if not widely purchased at \$42.50. Although I have not read the first edition, it is clear that the second has been largely rewritten. It reviews the properties of T and B lymphocytes and their stimulation by specific antigens and nonspecific mitogens in a thorough and readable fashion.

The first two thirds of the book deal with the descriptive biology of lymphocytes, their subpopulations and properties, methods of culturing them, their *in vitro* responses to soluble antigens, allogeneic cells (mixed lymphocyte reactions) and nonspecific mitogens, (lectins, bacterial products, antibodies to surface antigens), and the properties of activated lymphocytes. Though they present a reasonably up to date review, these chapters are considerably weakened by the omission, or cursory treatment, of various recent and exciting advances in cellular immunology that are relevant to lymphocyte stimulation. Examples of these are the I-region associated antigens (Ia), the physical association of $\beta 2$ -microglobulin with the major histocompatibility antigens, the possibility of cooperation between subpopulations of T cells (which may under some circumstances recognise different histocompatibility antigens) in the generation of cytotoxic cells, and the general importance of suppressor T cells.

The final third of the book deals with what is known about the molecular mechanisms of lymphocyte activation and the metabolic changes occurring during the activation process. These chapters, which deal almost exclusively with lectin stimulation of T lymphocytes, are thorough and well reasoned, and are the best discussion of this subject that I have seen. They provide an excellent background for anyone attempting to evaluate the most recent evidence for the possible roles of Ca^{2+} and cyclic nucleotides in the early stages of the activation process.

I suspect that the first part of the book will be particularly useful to cell biologists interested in the lymphocyte as a model of induced cell prolifera-

tion, and that the latter part will be of most interest to immunologists, who must in the end come to grips with the molecular biology of lymphocyte activation. The extensive bibliographies that follow each chapter should be invaluable to anyone working on and/or writing about lymphocyte responses.

Martin Raff

Combustion

Combustion: The Formation and Emission of Trace Species. By John B. Edwards. Pp. xiii+240. (Ann Arbor Science: Ann Arbor, Michigan; Wiley: Chichester, September 1974.) £10.80.

AN understanding of the genesis of air pollutants in combustion processes is an important and necessary prerequisite to the assessment and engineering of emissions control measures. This book goes some way towards providing a basic text, drawing together pertinent information previously scattered widely throughout the scientific literature. Choosing a predominantly chemical approach, the author has presented in five short chapters a non-mathematical account of premixed flames, secondary combustion processes (thermal reactors, after burners and catalytic reactors), diffusion flames and applications.

The non-mathematical treatment, doubtless adopted with a broad spectrum of readers in mind, has almost entirely precluded any discussion in depth and so the book fails to reach the level of a basic text and reference volume that is claimed of it; indeed a certain superficiality results in places. It would not satisfy the requirements of a British graduate course in science or engineering without considerable supplementation. On the other hand, it should serve admirably as an introductory text and as a guide for those whose primary concern is with other aspects of the air pollution problem.

Although the author admits to only minimal consideration of the detail of specific applications it is unfortunate that the final chapter is little more than an excellent selective bibliography of nearly 300 references. Treatment of one or two applications, even if only for illustrative purposes, would have given the reader an idea of the complex interactions between the chemical, engineering, economic and legal aspects of the emissions problem, thus adding context to the book.

Nevertheless, this useful volume fills a definite gap in the literature.

N. H. Pratt

Small points

The Mitochondria of Microorganisms. By David Lloyd. Pp. xii+533. (Academic: London and New York, January 1975.) £13.60; \$36.00.

MITOCHONDRIA have been the subject of study and speculation since around 1890 but until a satisfactory method of isolation was devised by Hogeboom, Schneider and Palade in 1948, little progress was made. During the following 15 years immense effort was devoted to the study of oxidative phosphorylation in animal mitochondria but relatively little attention was given to the mitochondria of yeasts, moulds and protozoa. The isolation of mitochondrial DNA in 1964 and the demonstration that this DNA had genetic independence made eukaryotic microorganisms attractive as tools for the study of mitochondrial function.

Until now, however, there has been no adequate text book for those entering the field so that in writing this book, David Lloyd has no competitors. This is not an easy book to read but it is accurate, up to date and comprehensive; indeed, the difficulty presented to the reader is occasioned largely as a result of the determination of the author to leave no unexplored corners. Most of the significant work on mitochondria has been done with organelles from animals, yeasts or neurospora, but other lesser known organisms are covered so thoroughly in the text that at times it is difficult to distinguish the significant from the somewhat trivial. This is, however, a minor criticism of a very worthwhile text book. It is symptomatic of the changed outlook in the field that relatively little attention is devoted to oxidative phosphorylation and that the main emphasis is on biogenesis and on genetics of mitochondria. But there is an excellent and very necessary review of the need for good, clean, undamaged mitochondrial preparations if meaningful results are to be obtained.

It is no easy matter when publishing a major textbook to ensure that it is up-to-date. Dr Lloyd is to be congratulated, therefore, on his success in this respect. The book is divided into three parts: first, structure and function; second, biogenesis; and finally, evolution; but it is not always easy, having read the text, to find again some particular bit of information which may be wanted. This is my only major criticism of a first class text book. More cross references within the text and a more comprehensive index would add greatly to the ease with which the vast amount of information collected by Lloyd could be used by his colleagues and by future students.

T. S. Work

obituary

Ove Frydenberg, known for his work in experimental population genetics of *Drosophila* and, in recent years, of protein variation in fishes, died in Denmark on April 7, at the age of 45.

After studying genetics and biometry at the University of Copenhagen, where he earned his Magister degree in 1955, he joined the staff of the Genetics Department there and lectured on population genetics and evolution. He also lectured on human genetics at the Dental School and served as consultant and collaborator for the barley genetics research group of the Danish Atomic Energy Commission. He spent two years in Brazil and one in the United States engaged in research and study. In 1964 he received his Dr Phil. from the University of Copenhagen. During this period his researches were diverse, including *Drosophila* systematics and genetic studies on barley, fish and humans. Also he was clearly one of the first to engage in a critical dissection of the selection process, using *Drosophila* as a tool. In 1967 he was given the mission of establishing a genetics institute at the University of Aarhus where he was appointed Professor and Chairman. His eight years of leadership resulted in a vigorous teaching and research organisation of international stature. During this last phase of his career he became an important figure in the Scandinavian science community. He wrote textbooks for Danish schools and popular articles on genetics. He was a board member of the Scandinavian Genetics Society and member of the Advisory Board of the Danish Atomic Energy Commission, Danish National Scientific Research Council

and Royal Academy of Science and Letters. He completed a full and productive career during his short life.

Max Rudolf Lemberg, who died in Sydney on April 10, will be remembered for his contributions to pyrrole chemistry and biochemistry, as a pioneer of Australian biochemistry and as a Quaker.

Born in Breslau in 1896, his first post-doctoral work was in heterocyclic chemistry with Heinrich Biltz of Breslau University. After a short period finding that he did not like industry, he accepted Freudenberg's invitation in 1925 to work on natural products at Heidelberg University. There he acquired his special skills in bile pigment chemistry, with several prized victories over the Hans Fischer school which then dominated tetrapyrrolic chemistry. He demonstrated that the chromoproteins of the red and blue algae bear a bile pigment chromophore by isolating crystalline mesobiliverdin ester; he showed that oocyan and uteroverdin were both biliverdin and that the 'green haemin ester' of Warburg and Negelein was not a haemin but biliverdin ferrichloride ester. In 1933 he was forced to leave Germany, and went to Cambridge where he had previously come under the influence of Hopkins, Barcroft and particularly Keilin who had much influence on his future interests. From Cambridge he accepted in 1935 an appointment as Director of the Biochemical Laboratories at the Institute of Medical Research in the Royal North Shore Hospital of Sydney. With the help of J. W. Legge, among other colleagues, he elaborated the sequence

of initial oxidative ring opening of the tetrapyrrolic macrocycle while the iron was still present, followed by removal of the iron to form biliverdin which in turn could be reduced by a specific liver reductase to bilirubin. This is today the accepted pathway of haem catabolism to bile pigments. Lemberg's next field was another green haem, the prosthetic group of cytochrome oxidase. He first attacked this through a study, with the late J. E. Falk, of the effect of side chains and their order on the spectra of porphyrin and the corresponding haems and haemochromes. This was followed by painstaking development of methods of isolating the rather labile porphyrin *a* with identification of several side chains. He then worked until his retirement on the mechanism of the reaction of cytochrome oxidase with oxygen, including the spectroscopic nature of the first components with oxygen and the accompanying conformational changes. Lemberg's study of the literature was meticulous and systematic and this appears in his two books, *Haematin Compounds and Bile Pigments* by Lemberg and Legge has been the standard work on the subject since its appearance in 1949. *The Cytochromes* by Lemberg and Barrett appeared in 1973 and critically reviews the literature from 1949 to 1972. Of many public recognitions Lemberg prized most his election to the Royal Society in 1952 and his appointment in 1956 as Professor Emeritus of Heidelberg University. He gave time generously to scientific societies and national committee work and was a foundation member of the Australian Academy of Sciences and of the Australian Biochemical Society.

announcements

Awards

The National Academy of Sciences has announced the election of the following as new members in recognition of their distinguished and continuing achievements in original research: S. A. Adler, H. N. Andrews, C. E. Ballou, G. S. Becker, E. P. Benditt, B. J. L. Berry, H. S. Bloch, B. S. Blumberg, M. Boudart, K. E. Boulding, F. A. Bovey,

R. O. Brady, Jr, J. R. Brobeck, C. M. Brooks, J. J. Burns, G. W. Burton, K. M. Case, B. Chalmers, M. W. Chase, M. J. Cohen, Z. A. Cohn, J. P. Collman, L. N. Cooper, G. M. Cox, E. C. Creutz, F. A. de Laguna, A. H. Doermann, P. Elias, W. G. Ernst, H. Federer, E. Feenberg, G. Feher, H. Frauenfelder, D. Fultz, P. R. Garabedian, R. G. Gordon, C. W. Gottschalk, H. Z. Griliches, R. E. Gross,

F. M. Haurowitz, W. Henle, R. L. Hill, R. H. Holm, D. M. Horstmann, L. M. Hurvich, D. Jameson, R. W. Kates, K. I. Kellermann, J. C. Kiefer, D. E. Knuth, A. H. Lachenbruch, E. N. Lorenz, E. Margoliash, M. V. Mathews, M. Mead, E. T. Mertz, M. F. Morales, J. N. Morgan, E. W. Mueller, D. B. Mumford, J. E. Myers, A. A. Penzias, V. R. Potter, P. B. Price, Jr, C. F. Quate, R. Radner, W. P. Rowe, H. A.

Schneiderman, M. Schwartz, C. G. Shull, P. Siekevitz, H. E. Simmons, Jr, E. H. Spicer, C. M. Stein, D. F. Steiner, G. J. Stigler, G. Streisinger, I. Tamm, G. Weber, J. C. Wheatley, H. C. White, R. H. Whittaker, R. S. Yalow.

The National Academy of Sciences has announced the election of the following as foreign associates: W. Beermann, C. de Duve, R. Hill, N. K. Jerne, K. Kodaira, D. Lal, E. J. Opik, A. E. Ringwood, M. C. Mendes da Rocha, Sir Martin Ryle, E. N. Sokolov, G. Wilkinson.

The following awards have been made by the British Institute of Radiology: **Barclay Medal** to F. Doyle (pathogenesis and radiological appearances of metabolic bone disease); **Barclay Prize** to F. Storer; **Röntgen Prize** to H. Hewitt (comparative survival of irradiated tumour cells).

Appointment

G. W. Fenton has been appointed to the chair of mental health at the Queen's University, Belfast.

International meetings

July 20–28, **Regulation of metabolic pathways**, Bogota, Columbia (Dr C. Corredor, Bioquímica, Facultad de Medicina, Universidad del Valle Apartado Aereo 2188, Cali, Colombia).

July 22–25, **Mechanisms of protein-hormone action**, Fort Collins, Colorado (Dr Lloyd Faulkner, Chairman, Local Committee, SSr, Department of Physiology and Biophysics, Colorado State University, Fort Collins, Colorado 80521).

July 22–25, **Cryogenic engineering conference**, Kingston, Ontario (L. Kenneth Armstrong, National Bureau of Standards, Boulder, Colorado 80302).

July 26–27, **Active intermediates: formation, toxicity and inactivation**, Turku, Finland (Dr Harri Vainio, Department of Physiology, University of Turku, Kiinamyllynkatu 10, SF-20520 Turku 52, Finland).

July 28–30, **Heavy metals as environmental hazards**, Bristol (Miss M. V. Auguste, The Chemical Society, Burlington House, London W1V 0BN, UK).

July 28–30, **Conduction and breakdown of dielectric liquids**, Delft (Dr J. M. Goldberg, Chairman, Organising Committee, Department of Applied Physics, Delft University of Technology, Lorentzweg No. 1, Delft, The Netherlands).

Person to Person

London accommodation. American professor and family desire 3 bedroom apartment or small home within 20 min of Imperial Cancer Research Fund Laboratories for 1 year, beginning July or September, 1975. Prefer Hampstead Heath area (Dr I. Diamond, Department of Neurology, University of California, San Francisco, California 94143).

Toronto house. University of Toronto scientist seeks a responsible family for his furnished house while he is on sabbatical leave. Four bedrooms, convenient schools and public transportation. Available from September 1, 1975 to August 31, 1976 (Dr A. Goodridge, C. H. Best Institute, 112 College Street, Toronto, Ontario, Canada M5G 1L6).

Sea sticklebacks. Wanted: shipment of live sea sticklebacks. *Spinachia vulgaris*. For details: Dr G. E. Moodie, Department of Biology, University of Winnipeg, Winnipeg, Manitoba, Canada R3B 2E99.

There will be no charge for this service. Send items (not more than 60 words) to Robbie Vickers at the London office. The section will include exchanges of accommodation, personal announcements and scientific queries. We reserve the right to decline material submitted. No commercial transactions.

Reports and publications

Great Britain

Agricultural Research Council. Animal Breeding Research Organization—Report 1975. Pp. 40. (Edinburgh: Animal Breeding Research Organization, West Mains Road, 1975. Obtainable from HMSO, Edinburgh and London.) 75p.

The Development of Radio. By Ian Trethowan. (BBC Lunch-Time Lectures, Ninth Series, No. 4.) Pp. 15. (London: BBC, 1975.)

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